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1.—The genus Tandya in Western Australia, with a description of a new opisthognathid fish, Tandya reticulata sp. nov.

by R. J. McKay*

Manuscript received 9 April 1968; accepted 21 May 1968

Abstract

A new species of opisthognathid fish belonging to the genus *Tandya* is described, and a key to the genus in Western Australia is provided.

Introduction

These small to moderate sized fishes, known as Smilers, Jaw-fishes or Monkey-fishes are generally found on tropical coasts of the world. In Australia the family is represented by three genera and eight species, one of which is described below as new. Revisions of the family are given by Ogilby (1920, pp. 21-30), and Whitley (1966, pp. 239-241).

Key to the Monkey-fishes of Western Australia

A. Interorbital width 16 to 27 percent of eye diameter, and 7.4 to 8.5 percent of head length. A conspicuous black spot or blotch between the third and seventh dorsal spines; soft dorsal, caudal, and anal fins with oblique dark bars or with black spots. Pectoral and ventral fins spotted. Body densely covered with fine black spots or blotches .... *Tandya darwiniensis*

B. Interorbital width 25 to 44 percent of eye diameter, and 9.3 to 10 percent of head length. No black blotch on anterior of dorsal fin; soft dorsal, caudal, and anal fins usually dark. Pectoral and ventral fins without spots. Body with irregular, scattered dark spots .... *Tanyda inornata*

C. Interorbital width 71 percent of eye diameter, and 14 percent of head length. No black blotch on anterior of dorsal fin; soft dorsal, caudal, and anal fins without spots or markings. Body with pale chain-like reticulate network enclosing one or more dark brown spots. Base of pectoral fins with a dark brown spot. Ventral fins without spots .... *Tandya reticulata* sp. nov.

Genus TANDYA Whitley, 1930

Tandya Whitley, *Mem. Qld. Mus.* 10 (1): 19. Type by original designation, *Opisthognathus maculatus* Macleay, 1878.

Tandya reticulata, sp. nov.

(Fig. 1)

D.XII, 16; A.ii, 14; Pect. 21. V 1, 5. C.2, 11, 2. Gill rakers on first branchial arch 8/14. Lateral line ca. 120, ending below eighth dorsal ray.

* Western Australian Museum, Perth, Western Australia

Head (100 mm) 3.3, depth of body (91) 3.6, depth of caudal peduncle (36) 9.0, length of caudal peduncle (22) 14.8, snout tip to dorsal fin origin (90 mm) 3.6 in standard length (325). Eye (20) 5.0, interorbital (14) 7.1, snout (7) 14.0, length of pectoral fin (50) 2.0, length of ventral fins (50) 2.0 in head length.

Head naked. Maxillaries extending almost two eye diameters beyond orbits; their posterior margins somewhat truncate. Outermost teeth in both jaws enlarged; two to three rows of small conical teeth followed by a row of slightly larged recurved teeth near the symphyses of both jaws; lateral teeth enlarged, in a single row. No teeth on the vomer, palatines or tongue. Eyes relatively small and separated by a wide, slightly concave interorbital space. Anterior nostrils with a well developed posterior flap; posterior nostrils with low rims. Opercles unarmed; the preopercular margin rounded, the opercle ending in a narrowly rounded flap at upper margin.

Body with small cycloid scales extending almost to the base of the pectoral fin, and becoming embedded above the opercular flap. Isthmus and around ventral fin bases naked. Belly covered with small, non-imbricate scattered scales, gradually becoming imbricate on sides.

Dorsal fin originates above posterior margin of operculum, a little before hindmost margin of the opercular flap. Anal fin originating below third dorsal ray, the length of the longest anal ray (48 mm) exceeds that of the longest dorsal ray (42 mm). Ventral fins jugular, the spine is short and embedded in thick skin, the first two rays are thickened.

Colour after preservation: Head pale brown with scattered dark brown to black blotches and finer spots; scattered reticulate pale markings are present, and well developed on the operculum. Maxillaries with scattered brown and white blotches, and with three poorly defined cross-bars. Body light golden brown with a network of chain-like reticulate pale markings enclosing one or more dark brown blotches within each mesh. Pectoral fin with a conspicuous dark brown spot on each side of the base. Soft dorsal, anal and ventral fins pale, without dark markings.

Described and figured from the unique holotype registered in the Western Australian Museum collection P.15758, collected by Inspec-

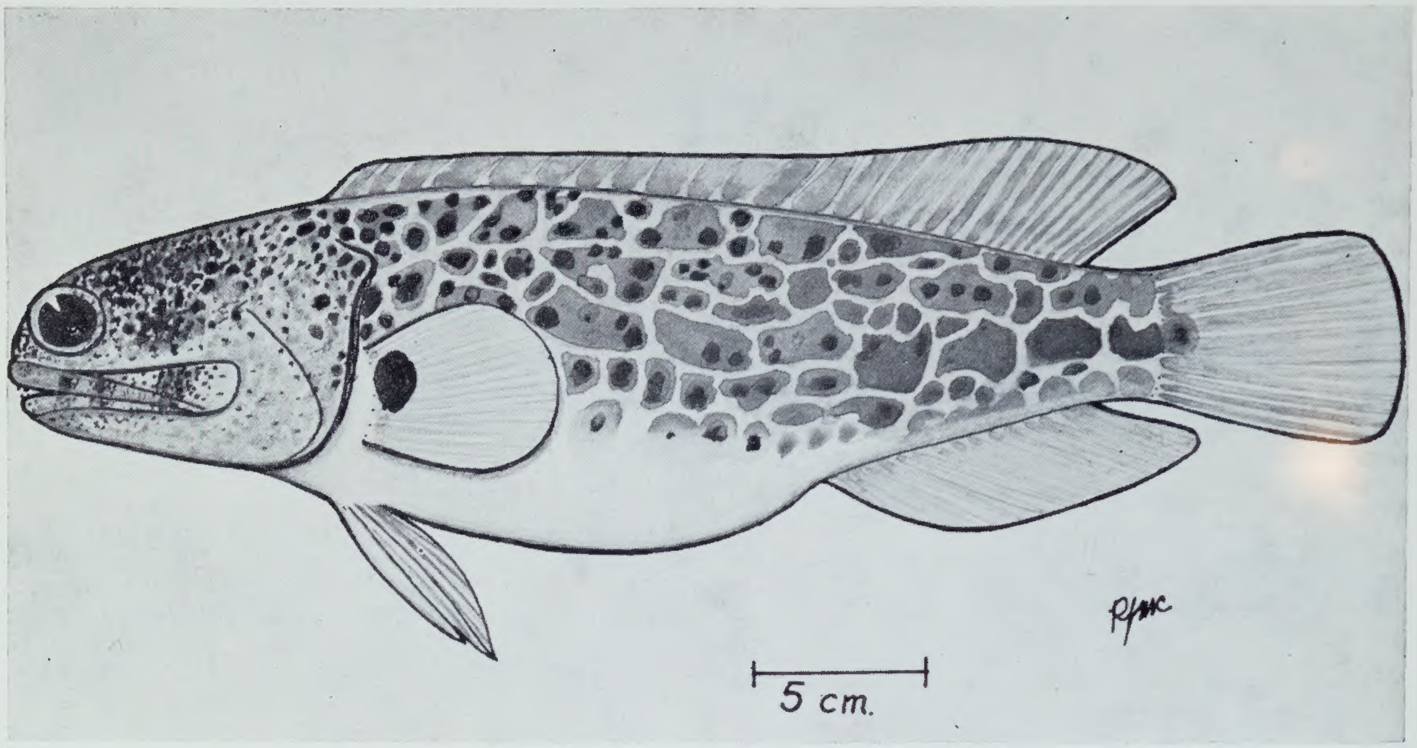

Figure 1.—*Tandya reticulata* from Broome, W.A.

tor R. J. Baird, September 1, 1965, Broome, Western Australia. Total length of holotype 385 mm.

This attractive new species may be readily distinguished from all other species in the genus in having a relatively small eye, a wide interorbital space, and a most distinctive coloration.

Tandya inornata (Ramsay and Ogilby)

Opisthognathus inornatus Ramsay and Ogilby, 1887, *Proc. Linn. Soc. N.S.W.*, (2) 2: 561.

Originally described from two specimens collected at Derby, this species was later figured by McCulloch (1914, p. 215, pl. XXX) who illustrated one of the syntypes, substituting the coloration for that of a large specimen collected at Port Hedland (No. 10704 W.A. Museum collection). Additional specimens are now recorded from Broome (P.559) and Point Samson (P.7076). Ramsay and Ogilby (1887, p. 561) state that the eyes are about one quarter of their diameter apart. The interorbital width of specimens No. 10704 (S.L. 393 mm) and P.7076 (S.L. 365 mm) are 44 and 40 percent of eye diameters respectively.

Ion L. Idriess devotes a whole chapter describing the interesting habits of a large Monkey-fish from Broome in his book "Forty Fathoms Deep". The fact that Idriess records the coloration of the small wrasse that lives in the same hole as his Monkey-fish, whilst not mentioning the colour of his main subject, suggests that the Monkey-fish might be the drab *T. inornata* rather than the ornate *T. reticulata*. As Idriess's specimen measured about eighteen inches in length, it is unlikely to be the small. *T darwiniensis*.

Tandya darwiniensis (Macleay)

Opisthognathus darwiniensis Macleay, 1878, *proc. Linn. Soc. N.S.W.*, 2: 355, pl. IX, fig. 3.

In the Western Australian Museum collection this species is represented as follows: Broome (P.15758), Point Samson (P.5062), Monte Bello Islands (P.4357, P.4390), tidepools on Locker Island, near Onslow (P.7938, P.7939).

I have observed this species living in holes dug in the sand near coral reefs at the Monte Bello Islands in a depth of about ten feet. It is a voracious fish and will take a surprisingly large bait. Macleay's specimen from Darwin measured about 153 mm and none of our specimens is greater than 208 mm. This species appears then to be the smallest of the genus in Australian waters.

Mees (1959, p. 8) surmised that *T. darwiniensis* was the juvenile of *T. inornata*, but an examination of P.4390, a female with a standard length of 150 mm revealed it to be sexually mature with large ova measuring approximately 3 mm in diameter.

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2.—Some microplankton from two bores at Balcatta, Western Australia

by Isabel C. Cookson* and A. Eisenack**

Manuscript received 21 May 1968; accepted 17 September 1968

Abstract

Eleven dinoflagellate species and one acritarch are described from the Osborne Formation, of Albian-Cenomanian age, in the Perth Basin of Western Australia. Two new genera, *Conosphaeridium* (type species: *Hystrichosphaeridium striatoconus* Deflandre and Cookson) and *Xenascus* (type species: *Xenascus australense* Cookson and Eisenack n.sp.) are proposed. The following new species are instituted: *Deflandrea glabra*, *Deflandrea balcattensis*, *Xenascus australense* and *Conosphaeridium tubulosum*.

Introduction

This paper is concerned with a few of the many types of microplankton present in some samples of the upper portion of the Osborne Formation from two bores sunk by the Perth Metropolitan Water Supply at Balcatta, about 8 miles north of Perth, Western Australia. Balcatta Bore No. 1, which reached a total depth of 2,500 feet, was drilled near the junction of Albert Street and Ronald Street; Balcatta Bore No. 2, which reached a depth of 2,401 feet, was drilled near the intersection of Albert Street and North Beach Road. The Osborne formation is regarded as of Albian-Cenomanian Age (McWhae *et al* 1958 p. 143). The succession in these boreholes (depths in feet) is as follows:

Balcatta No. 1		Balcatta No. 2
0 - 110	Quaternary Sand	0 - 107
110 - 520	Osborne Formation	107 - 510
520 - 2000	South Perth Formation	510 - 1810
2000 - 2500	Yarragadee Formation	1810 - 2401 T.D.

We are indebted to Mr. J. H. Lord, Director of the Geological Survey of Western Australia and Dr. B. E. Balme, University of Western Australia for the gift of samples and Dr. A. E. Cockbain for information regarding the locality and age of the deposits concerned.

The holotypes will be housed in the palaeontological collection of the Geological Survey of Western Australia. Numbers prefaced by the letter F are registered numbers in that collection.

Systematic descriptions

Dinoflagellata

Family *DEFLANDREACEAE* Eisenack

Genus *Deflandrea* Eisenack 1938

Deflandrea glabra n.sp.

(Figure 1,A holotype F6629)

Occurrence. Balcatta Bore No. 1, between 220-227 feet, and 240 feet, Bore No. 2 at 220 feet.

Description. Shell considerably longer than broad with convex sides that slant towards both apex and antapex. The apex ends in a short and bluntly pointed horn; the antapex is truncate or slightly concave with a sharply pointed horn on one side. There is no indication of tabulation, girdle or longitudinal furrow. Both the outer wall and that of the capsule are thin and smooth. The capsule is spherical in outline and does not extend to the lateral walls. The archeopyle is relatively large, trapezoidal with rounded corners.

Dimensions. Holotype-length 95 μ width 52 μ Range-length about 95-142 μ width about 52-82 μ.

Comment. The shape of *D. glagra* is close to that of *D. belfastensis* Cookson and Eisenack 1961 from an Upper Cretaceous deposit in the Belfast North Bore in S.W. Victoria, between 4645 and 4652 feet. However the wall of *D. belfastensis* is prominently granular, whereas that of *D. glabra* is smooth.

Deflandrea balcattensis n. sp.

(Figure 1, B-F, holotype Figure 1,B, F6630)

Occurrence. Balcatta Bore No. 1, 120-160 feet, 230-270 feet. Balcatta Bore No. 2 at 150 and 200 feet.

Description. Shell smooth, rather flat, roughly oval in outline divided unequally by a relatively broad, deep girdle the hypotheca being shorter than the epitheca. The sides of the epitheca, which are convex, narrow distally towards a short truncate apex. The wall of the hypotheca narrows gradually, one side usually being longer and somewhat convex, the other shorter and slightly oblique, so that the antapex is situated, more or less, to one side of the mid-line. An archeopyle has not been evident. A characteristic feature of the ventral surface has been the constant presence, in the mid-line just below the lower limits of the girdle, of a short, wavy, longitudinal thickening (Fig. 1 E, F) closely similar to that associated with the flagellum in some living dinoflagellates. The capsule, which is well defined and approximately spherical, does not quite fill the shell laterally. Its wall is smooth, unornamented, and relatively thick.

Dimensions. *Holotype*—overall length 72 μ, overall width 52 μ, capsule about 38 x 42 μ. Range—overall length about 55-72 μ, overall width about 38-52 μ.

Comment. *D. balcattensis* is obviously closely related to *D. rotundata* Eisenack and Cookson 1960, from an Albian deposit in the Oodnadatta Bore, South Australia, at 3221 feet and *D. foliacea* Eisenack and Cookson 1960 from Upper Cretaceous deposits such as the Upper Gearle Siltstone and the Molecap Greensand in Western Australia. In both, as in *D. balcattensis*, an *archeopyle* is apparently not developed, a feature which casts some doubt as to their close affinity with the genus *Deflandrea*. In neither *D. rotundata* nor *D. foliacea* has the small wavy thickening, invariably present on the mid-ventral surface of *D. balcattensis*, been evident.

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** University of Tubingen, Germany.

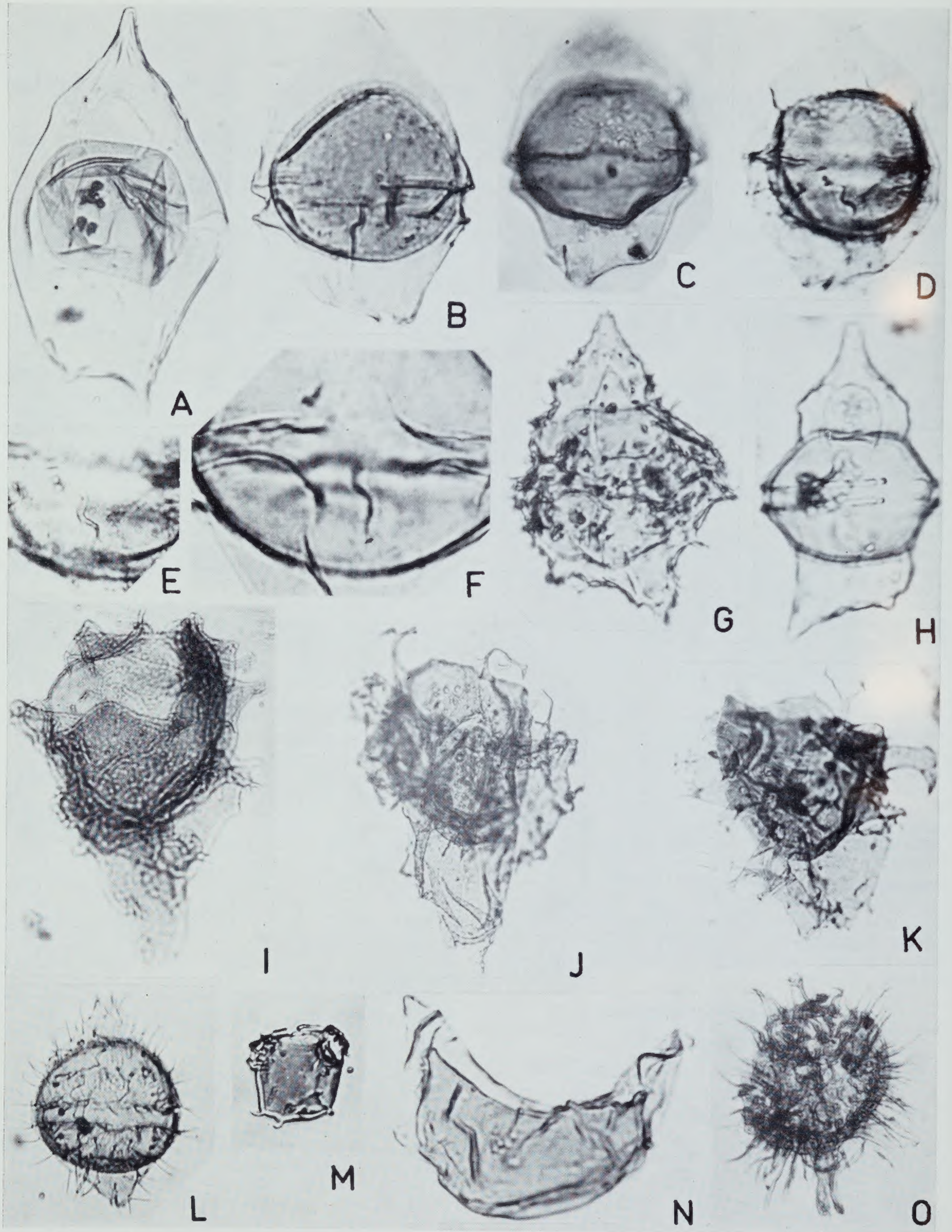

Figure 1..—A.-*Deflandrea glabra* n.sp. Holotype, x700. B-F.-All *Deflandrea balcattensis* n.sp. B.-Holotype, x700. C.-Dorsal surface of paratype, x700. D-F.-Ventral surfaces showing flagellum-like structures D.- x640. E.- x1000. F.- x1500. G-*Deflandrea* cf. *echinoidea* Cookson and Eisenack, x700. H.-*Deflandrea tripartita* Cookson and Eisenack. x500 I-K.-*Xenascus australense* n.sp., J holotype, I and K paratypes, all x400. L.-*Palaeohystrichophora infusorioides* Deflandre, x500., M.-*Gillinea hymenophora* Cookson and Eisenack, x500. N.-*Diplotesta luna* Cookson and Eisenack, x700. O.-*Coronifera oceanica* Cookson and Eisenack, x450.

Such a feature has been recorded as present in several Australian Tertiary species (Cookson and Eisenack 1965 pp. 134, 140). *D. balcattensis* also bears some resemblance to *D. perlucida* Alberti (1959, pl. 9, fig. 6, 7) from a German Upper Barremian deposit.

Deflandrea cf. echinoidea Cookson and Eisenack 1960

(Figure 1,G)

Deflandrea echinoidea Cookson and Eisenack 1960, p.2, pl. 1, fig. 5, 6.

Occurrence: Balcatta Bore No. 1, samples between 120-200 feet, 120-160 feet and 170 feet, and Bore No. 2 at 150 feet.

Dimensions. Length 50-70 μ, width 33-47 μ.

Comment. The form of *Deflandrea* which herein is compared with rather than assigned to *D. echinoidea* is not uncommon in the Mid-Cretaceous deposits referred to above. It differs from the Upper Cretaceous figured specimens from the Gingin and Toolonga areas, Western Australia, in the smaller size-range, the coarser and more sparsely arranged spines and to some extent the shape of the whole shell. However, since *D. echinoidea* is the only definitely spiny *Deflandrea* so far described we have refrained from treating the Balcatta form as a new species.

Deflandrea tripartita Cookson and Eisenack 1960

(Figure 1,H)

Deflandrea tripartita Cookson and Eisenack 1960, p.2, pl. 1, fig. 10.

Occurrence. Balcatta No. 1 bore, at 170 and 180-210 feet.

Comment. Several examples similar to the one on Figure 1, H have been recovered from the Balcatta Bore No. 1 at 170 and 180-200 feet (B. E. Balme sample 14800). The surface of the shell is perfectly smooth, in contrast to the slightly and finely granular surface of the type specimen from the seismic shot hole, north of Gingin, at 160 feet.

Genus *Palaeohystrichophora* Deflandre 1934 emend. Deflandre and Cookson 1955

Palaeohystrichophora infusorioides Deflandre 1936

(Figure 1,L)

Palaeohystrichophora infusorioides Deflandre 1936, p.38, pl. 9, fig. 8.

Palaeohystrichophora infusorioides Defl. Cookson and Eisenack 1958, p.37, pl. 10, fig. 10.

Palaeohystrichophora infusorioides Defl. Cookson and Hughes 1964, p.43, pl. 5, fig. 8.

Comment. P. infusorioides has occurred occasionally in preparations of the Balcatta No. 1 Bore at 170 feet. It was earlier recorded by Cookson and Eisenack (1958) from the Western Australian Upper Cretaceous (Cenomanian to Lower Turonian) Gearle Siltstone, Wapet's Rough Range Well No. 8 at 1530-48 and Well No. 5 at 1570 feet.

Family *STEPHODINIACEAE* Eisenack

Genus *Stephodinium* Deflandre 1936

Stephodinium australicum Cookson and Eisenack 1962

Stephodinium australicum Cookson and Eisenack 1962, p.491, pl. 2, figs. 5-10.

Occurrence. Balcatta Bore No. 1 180-210 feet B. E. Balme, Sample 1480.

Comment. Only one poorly preserved example of *S. australicum* has been found during this study. This form was previously recorded by Cookson and Eisenack from several Western Australian Mid-Cretaceous, Upper Albian to Cenomanian deposits.

Family *HYSTRICHOSPHAERIDIACEAE* Evitt

Genus *Conosphaeridium* n. gen.

Description: Shell circular in outline with a single-layered wall of varying thickness and about 20 regularly distributed conical to cylindrical, striated appendages; archeopyle circular to polygonal.

Comment: The genus *Conosphaeridium* can be distinguished from all previously described members of the Hystrichosphaeridiaceae by the single-layered wall and the absence from the appendages of trumpet or funnel-shaped terminal expansions. In particular it differs from the genus *Lithosphaeridium* in the greater number of appendages.

Type species. Conosphaeridium striatoconus (Deflandre and Cookson) new combination.

Conosphaeridium striatoconus (Deflandre and Cookson)

Figure 2A-D

Hystrichosphaeridium striatoconus Deflandre and Cookson 1955, p.275, pl. 2, fig. 10, Fig. 36.

Occurrence. Gingin W.A., Molecap Hill, Lower Greensand, Balcatta Bore No. 1 between 120 and 160 feet, 220-270 feet Bore No. 2 at 200 feet.

Comments The Balcatta examples herein referred to *C. striatoconus* whilst having the general features of the figured paratype (Deflandre and Cookson 1955, pl. 2, fig. 10) have shown considerable variation in both size and shape of the appendages. However until more examples become available it seems better to broaden the species rather than to create a new one. One feature which still remains doubtful in this species is whether the apices of the appendages are normally open or shut. In the original description it was stated that the apex is "normally closed but is frequently broken off leaving a distinct opening into the process". On the basis of size of appendages we have distinguished two deviants (a) and (b) from one that comes close to the original examples.

Size of appendages. Typical form, Figure 2B, width 21-22 μ, length 18-20 μ. Form (a), Figure 2A, width 18-22 μ, length 12-17 μ. Form (b), Figure 2C, width 20-33 μ, length 20-30 μ.

Conosphaeridium tubulosum n. sp.

(Figure 2 E, F; holotype Figure 2F, F 2231)

Occurrence: Balcatta Bore No. 1, 180-210 feet, B. E. Balme Sample 1480.

Description. Shell apparently circular in outline with relatively long, cylindrical to somewhat conical appendages with straight or slightly oblique openings, the edges of which are somewhat crenulate or serrate. The walls of the appendages are longitudinally striated, the thickenings frequently extending along the whole length of the wall. The wall of the shell is moderately thin, unpatterned and readily crushable.

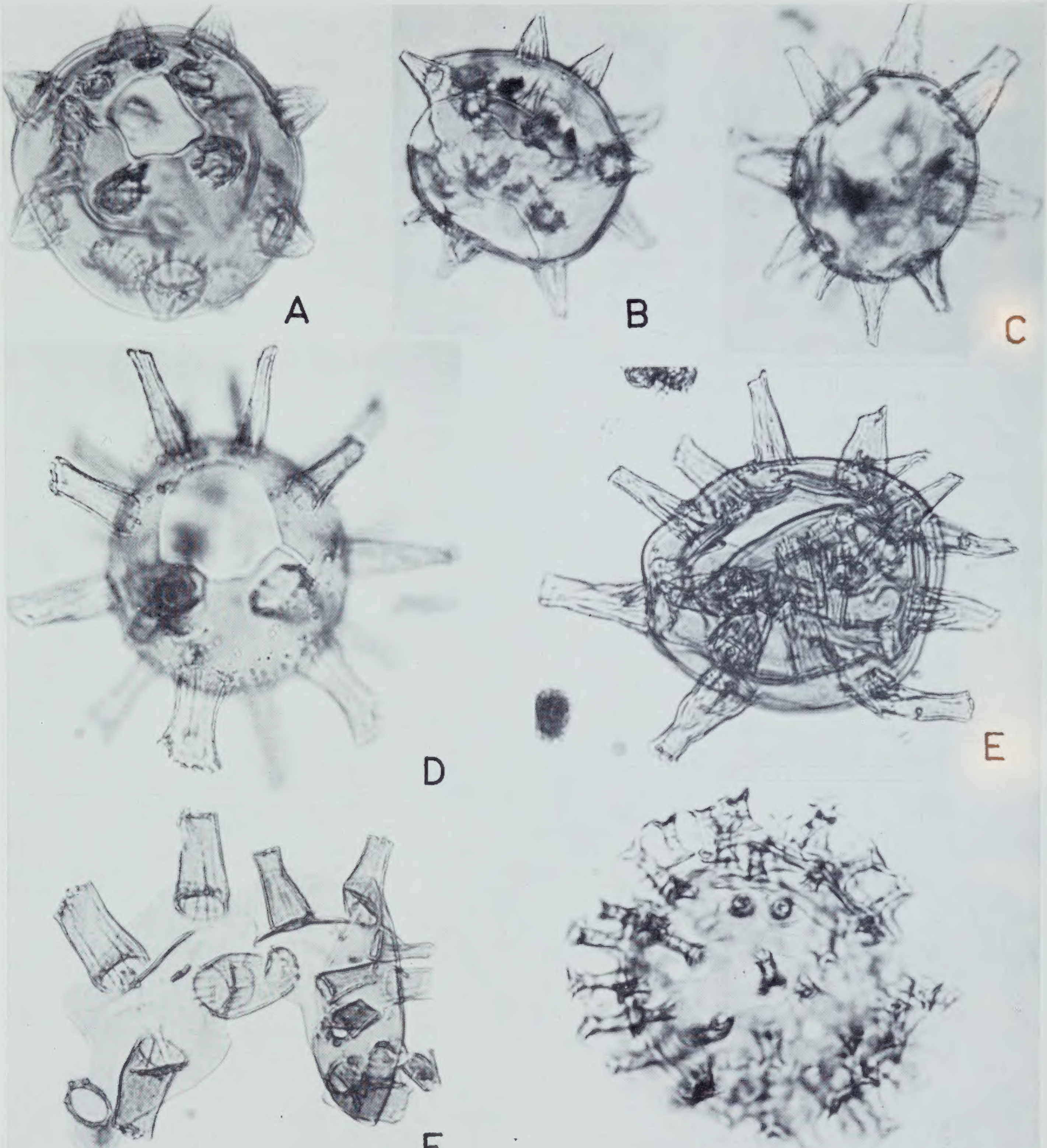

Figure 2.—A.-*Conosphaeridium* cf. *striatoconus*, x450. B-D.-*Conosphaeridium striatoconus* (Deflandre and Cookson), B and C, x350. D, x500. E and F.-*Conosphaeridium tubulosum* n.sp. E.-Holotype, x500. F.-Paratype, x500. G-J.-*Cleistosphaeridium ancoriferum* (Cookson and Eisenack). G.-x1100. H-J.-Appendages showing detailed structure, x1500.

Dimensions. Holotype: diameter of shell about 70 μ, overall diameter about 130 μ, appendages about 28-30 μ long, 8-10 μ wide. Range of appendages about 25-30 μ long.

Comment. C. tubulosum differs from *C. striatoconus* in both the shape and size of the appendages. In *C. striatoconus* they are relatively short and conical whereas in *C. tubulosum* they are relatively long, cylindrical or only slightly conical.

Genus *Cleistosphaeridium* Davey, Downie, Sarjeant and Williams 1966.

Cleistosphaeridium ancoriferum (Cookson and Eisenack)

(Figure 2, G-J)

Hystrichosphaeridium ancoriferum Cookson and Eisenack 1960, p. 8, pl. 2, fig. 11.

Hystrichosphaeridium ancoriferum Cookson and Eisenack; Cookson and Hughes 1964, p. 47, pl. 9, fig. 7.

Cleistosphaeridium ancoriferum (Cookson and Eisenack) Davey, Downie, Sarjeant and Williams 1966, p.167, pl. 6, fig. 5, pl. 9, fig. 1.

Cleistosphaeridium ancoriferum (Cookson and Eisenack) 1968.

Age and occurrence. Probably Albian, Balcatta Bore No. 1 at 219, 280 and 290 feet, and Bore 2 at 220 feet.

Comment. The specimens from the Balcatta Bores 1 and 2 agree completely with those of *C. ancoriferum* from the Gingin Brook Bore 4 between 402 and 404 feet (Cookson and Eisenack 1968). They further support the doubt therein expressed regarding the reference to this species of some Albian specimens from Surrey, England (Davey, Downie, Sarjeant and Williams 1966, p. 167).

Family Uncertain

Genus *Coronifera* Cookson and Eisenack 1958

(Figue 1,O)

Coronifera oceanica Cookson and Eisenack 1958, p.45, pl. 12, fig. 6.

Coronifera oceanica Cookson and Eisenack; Cookson and Hughes 1964, p. 56, pl. 9, figs. 8, 9.

Coronifera oceanica Cookson and Eisenack; Clarke and Verdier 1967, p. 77, pl. 17, fig. 7.

Coronifera oceanica Cookson and Eisenack 1968.

Comment. C. oceanica has occurred occasionally in the Balcatta No. 1 Bore at 120 and 170 feet. The shape of the antapical horn differs somewhat from that of the type and of an example recently recovered from Gingin Brook Bore 4, core 2, at 404-414 feet and a small horn-like structure is present at the apex.

Genus *Gillinia* Cookson and Eisenack 1960

Gillinia hymenophora Cookson and Eisenack 1960

(Figure 1,M)

Gillinia hymenophora Cookson and Eisenack 1960, p. 11, pl. 3, figs. 4-6.

Comment. G. hymenophora, originally described and recorded from a relatively large number of Western Australian Upper Cretaceous deposits (Senonian to Turonian), has occurred in Balcatta No. 1 bore at 170 feet.

Genus *Xenascus* n. gen.

Description. Shell consisting of a relatively thick-walled central body circular to slightly oval in outline, and a thinner, completely separate investing layer, the space between which being widest in the anatapical region. The outer layer bears appendages of variable size and shape. A large apical archeopyle, somewhat angular in outline, is developed.

Type species. Xenascus australense n.sp.

Xenascus australense n.sp.

(Figure 1,I-K; holotype Figure 1,J, F6632)

Occurrence. Balcatta No. 1 Bore at 170 and 180-210 feet.

Description. As for the genus. Both the inner and outer layers of the shell are finely and closely granular. The appendages vary both in number and size in individual specimens, some are simple, others forked, but all have somewhat flattened apices.

Dimensions: Holotype—overall length about 142 μ, overall width about 100 μ, central body about 76 x 68 μ. Range—overall length about 109-156 μ, overall width about 76-133 μ, central body about 70-76 μ long, about 68-76 μ broad.

Acritarcha Evitt

Subgroup Dinemorphitae Downie, Evitt and Sarjeant 1963

(= Diplotestidae Cookson and Eisenack 1960 (pars.))

Genus *Diplotesta* Cookson and Eisenack 1960a

Diplotesta luna Cookson and Eisenack 1960b

(Figure 1, N)

Diplotesta luna Cookson and Eisenack 1960b, p. 10, Pl. 3, fig. 21.

Diplotesta luna Cookson and Eisenack 1962, p. 497, pl. 4, fig. 18, 19.)

Diplotesta luna Cookson and Eisenack; Manum and Cookson, 1964, p. 26, Pl. 5, fig. 9.

Comment. D. luna has appeared infrequently in the Balcatta Bore No. 1, between 220 and 270 feet (B. E. Balme sample No. 1479). It was originally recorded from an Upper Albian to Cenomanian deposit at Gingin, Western Australia (Wapet's seismic shothole B1 at 210 feet). The occurrence of *D. luna* in a Cretaceous sample from Graham Island, Arctic Canada is of interest (Manum and Cookson 1964).

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3.—A blind mygalomorph spider from a Nullarbor Plain cave

by Barbara York Main*

Manuscript received 21 May 1968; accepted 17 September, 1968

Abstract

Extensive exploration of Nullarbor Caves in recent years has revealed the existence of an arthropod cave fauna, including three species of blind spiders. Fragments of a blind mygalomorph spider (Dipluridae: Diplurinae) have been collected. This spider is here described as a new genus and species—*Troglodiplura lowryi*.

Introduction

Several cave-dwelling spiders have for long been known in Australia, the most notable is the "Tasmanian cave spider", *Hickmania troglodytes,* which is a relict species of the family Hypochilidae (Goede, 1967). Equally well known at least to speleologists, in the limestone caves of south west of Western Australia, is the large *Epimecinus tegenarioides* (Dictynidae). Both of these spiders occur in the twilight zone and *Hickmania* at least is also frequently found in sheltered situations outside caves. Neither of these species nor any of the other spiders previously observed in caves in Australia show any special modifications to a cave existence.

As a result of extensive exploration, in recent years of Nullarbor caves and the collection from them of fauna, several troglobitic creatures have been discovered. Mackerras (1967) described the blind cockroach, *Trogloblatella nullarborensis,* of which living specimens have been collected from several caves. Three living specimens of two species of blind araneomorph spiders have also been collected and are to be described elsewhere by M. G. Gray. In addition, fragments of a blind mygalomorph spider were found amongst remains of cockroaches and beetles collected by D. C. and J. W. J. Lowry in August 1966 from Roaches Rest Cave, 27 miles NE of Madura. Amongst these fragments were two tarsi each with three claws attached. The bipectinate upper tarsal claws determined the specimen as a member of the sub-family Diplurinae of the Dipluridae. The broad carapace and the shape and position of the sternal sigilla (distant from the margin) preclude the specimen from being placed in either of the diplurine genera commonly found on the surface of the Nullarbor Plain, *Chenistonia* and *Dekana*. In these two features I regard it as distinct from all known Diplurinae.

One is necessarily reluctant to erect a genus on the basis of such fragments and it is to be hoped that further collecting will yield living material. However since no living creatures have been observed in Roaches Rest Cave (J. W. J. Lowry, personal communication) and bearing in mind that surface distribution of such a blind spider would be difficult, the possibility that it is extinct must be considered. Therefore it seems justifiable to record the occurrence without waiting for possible intact or living specimens. If still extant the Mygalomorph would presumably live in a burrow, possibly with silk prey-trap extensions in detritus of the cave floor, or in a silk tube on the walls or roof of the cave, thus rendering it less conspicuous than either the cockroaches or the other two species of spiders.

Troglodiplura gen. n.

With the general characters of the sub-family Diplurinae, namely paired tarsal claws bipectinate. Cheliceral furrow with complete row of teeth on inner margin and an outer basal irregular group of granular teeth. Carapace broad with rounded sides, width approximating length; fovea straight and shallow. Eyes absent. Sternum broad, width approximating length; sigilla oval and situated well away from margin. Labium broad, deep anterior indentation. At least some tarsi dorso-ventrally curved and with scopula.

Troglodiplura lowryi sp. n.

Holotype: Sex ? Fragments only. Collected with cockroach fragments from Roaches Rest Cave, 27 miles NE of Madura (type locality), 29.viii.1966 by D.C. and J. W. J. Lowry. Deposited in the Western Australian Museum. Register Number WAM 68-342.

Fragments consist of: incomplete carapace with left chelicera, labium and anterior piece of sternum attached; right chelicera originally loosely attached but became free; two other fragments of sternum, one piece of which contains two posterior sigilla of left side; two maxillae (coxae of pedipalps); two anterior ? tarsi with claws intact and internally, strands of muscle. Colour of fragments a light brown or tan with tarsal claws and fangs of chelicerae black.

Carapace (Fig 1 A) incomplete, posterior median section missing. Broad with rounded sides. Glabrous, hairless but with a few 'pits' or 'sockets' from which hairs and bristles have become detached on anterior margin. Fovea straight. Eyes absent. Width at front of carapace, 5.0mm; width at widest part (across fovea), 9.7mm; approximate length, 10.5mm. [anterior margin to fovea, 6.50mm, fovea to posterior edge probably 4.0mm].

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Sternum with sparse scattered hairs and fine bristles (Fig. 1 B). Length (approximately) 5.0mm; width (approximately) 5.0 mm. Obtusely pointed posteriorly. Three pairs sigilla, broad ovoid outline; posterior sigilla approximately three times their long diameter from margin.

Labium, 1.9 mm wide, 1.0 mm long, anteriorly indented, with fine hairs and bristles (Fig. 1 B). *Maxillae* with group of cuspules on inner angle (Fig. 1 D, E).

Chelicerae with dorsal 'pits' indicating presence of now detached bristles. Furrow of right chelicera with nine large teeth on inner margin and a posterior group of about ten granules (Fig. 1 C). No teeth on outer margin.

Tarsus (a) with dorso ventral curvature. Scattered bristles and a few ventral apical slender spines, numerous 'pits' from which bristles detached. A ventral scopula of short dense pile. Length, 6.2mm. Upper claws

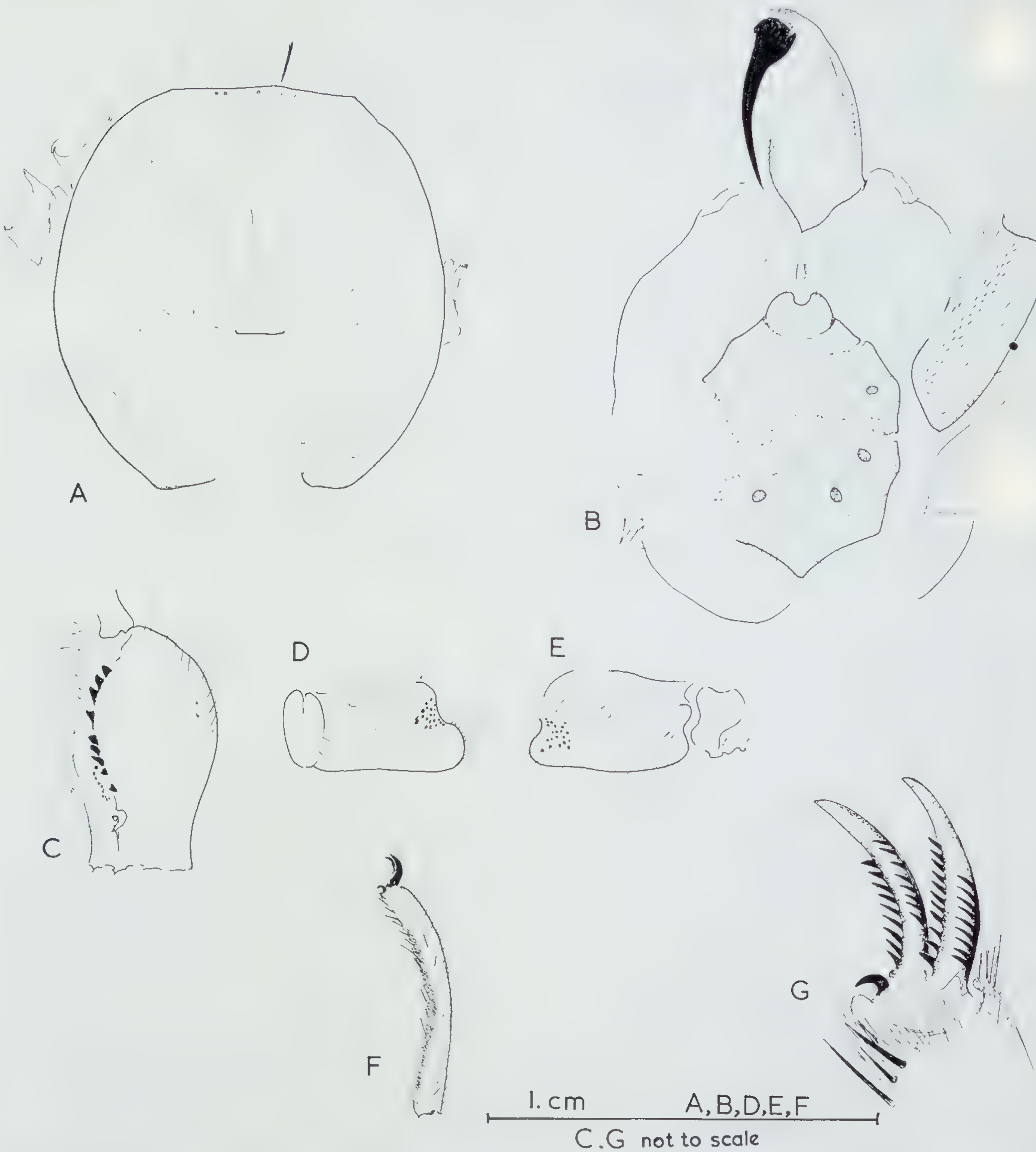

Figure 1.—*Troglodiplura lowryi* gen. et. sp. nov. A.-Carapace. B.-Ventral aspect carapace, sternum, labium, left chelicera. C.-Right chelicera. D, E.-Right and left maxillae; left maxilla rotated slightly backwards. F.-Tarsus (b). G.-Tarsal claws of tarsus (a).

bipectinate; one claw 9 outer, 8 inner teeth, the other claw with 9 outer and 11 inner teeth (Fig. 1 G). Median claw smooth.

Tarsus (b) (Fig. 1 F) length, 6.0mm. Short dense scopula. Hairs and bristles present. More sharply curved than first specimen. Pectinations on claws, 10 outer, 8 inner; 9 outer, 9 inner. It is not possible to tell whether tarsi are from left or right side but due to arched tendency are presumably of the first and second legs.

Habitat: Fragments were found amongst cockroaches collected by D. C. and J. W. J. Lowry, between 50 and 200 yards from cave entrance in total darkness, Roaches Rest Cave.

Discussion

The occurrence of a troglobitic mygalomorph from a Nullarbor cave is of interest for several reasons. First, although several mygalomorph spiders have been reported as inhabiting caves of tropical regions only two of these are blind species—*Accola caeca* Simon (Dipluridae) and *Troglothele caeca* Fage (Barychelidae). The Roaches Rest specimen is the only record of a cavernicolous Mygalomorph in Australia. Secondly it implies that the caves have been inhabited by other creatures for a very considerable time. For a predator, which is largely confined to a burrow, to have become established in a cavernicolous habitat and to have developed troglobitic characters, it must first have had an abundant and continuous prey source readily available. In this instance it is probable that the invertebrate food chain is dependent basically on bats—on the guano of which the cockroaches feed. The mygalomorph would probably feed on both cockroaches and beetles and in addition possibly crickets, and casual invaders of the caves.

Moore (1964) has commented on the paucity of Australian troglobites and the converse abundance of troglophiles and trogloxenes. This he interprets, at least for Tasmania and south eastern Australia, as due to a secondary invasion of cave habitats following extermination of primary troglobites due to hot dry interglacial periods of the Pleistocene. Moore suggested that New Zealand troglobitic beetles are hygrophilous relics of an early Pleistocene period. However it is possible that the Nullabor troglobites (spiders and cockroaches) are much older. Amongst other spiders collected from the Nullarbor caves there are no second level troglophiles as defined by Hamilton-Smith (1967). It would seem that the troglobites themselves are relics of a primary invasion which could date from any time subsequent to the fall in Miocene sea level and once a vegetation and fauna established on the surface. This would be in agreement with the suggestion that "cave genesis" on the Nullarbor Plain began during the Tertiary (Hamilton-Smith, 1967) and not as suggested by some authors, during the Pleistocene.

Acknowledgments

My thanks are due to Mr. and Mrs. D. C. Lowry who collected the spider fragments.

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4.—Observations on stylolites in Western Australian rocks

by J. E. Glover*

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Abstract

Stylolites are recorded and described from limestones, dolomitic limestones, dolostone, quartzite, chert and complex cherty iron-rich rocks. Their features are best explained by the pressure-solution theory of origin. Stylolite development causes loss of section, and in some limestones this may induce new structures in overlying strata. Dissolved calcite may precipitate and cement the limestone itself or nearby formations, and differential pressure-solution of calcite in dolomitic limestones can increase their proportion of dolomite. The potential importance of these phenomena should be considered in detailed investigations of limestone areas.

The origin of the quartz cement which makes many Western Australian sandstones too tight to be fluid reservoirs remains an enigma. Quartz cement in some sandstones elsewhere was apparently derived by pressure-solution of quartz grains, but this has not been established for Western Australian rocks examined.

Some stylolites in chert may be relicts of an earlier limestone fabric, whereas others occur in chert for which the hypothesis of primary deposition of silica is favoured. Even where replacement can be demonstrated, it may not be possible to decide if the stylolites are relicts.

Introduction

Definition

Stylolitic seams are defined by Pettijohn (1957) as surfaces marked by interlocking or mutual penetration of the two sides, with teeth-like projections on one side fitting into sockets on the other. They are far more common in limestones than in other rocks and are generally said to form by a process of pressure-solution. There has been controversy about their origin and even the derivation of the term, though it now seems agreed that the word ultimately came from *stylos*, a pillar or column (Pettijohn 1958).

Significance

Stylolitic seams were once considered to be sedimentary curiosities, but it is becoming increasingly appreciated that they are the results of processes that can be stratigraphically and economically important. Many authors have agreed that the formation of stylolites in limestones can lead to remarkable loss of section; some (Ramsden 1952, Dunnington 1954) have emphasized the role of stylolites in the accumulation of oil, and others (Ohle 1951, Towse 1957, C. W. Brown 1959, and Glover 1968), though differing in postulated mechanisms, have drawn attention to their role in concentrating dolomite in dolomitic limestones. It is likely that the loss of limestone section when abundant stylolites form can cause structural modification of overlying strata, and may release carbonate for the cementation of porous rocks elsewhere.

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Waldschmidt (1941), when investigating factors influencing migration of oil in the Rocky Mountains region, postulated a connection between the formation of interlocking grain boundaries and silicification in sandstones. Later, Heald (1955, 1956, 1959) also drew attention to the significance of pressure-solution in cementing sandstones. James (1951) used stylolites in deducing the petrogenesis of iron-rich rocks, and Blake and Roy (1949) used them in the structural interpretation of deformed rocks. The economic and petrogenetic significance attributed to some stylolites is sufficient justification for describing their occurrence in Western Australian sedimentary rocks, and for predicting where they may be expected.

Formation

The main dispute about stylolites has been whether they form in consolidated or unconsolidated sediments. The most ardent advocate of formation in unconsolidated sediments has been Shaub (1939, 1949, 1950, 1953, 1958), who postulated that narrow clay bands in calcareous muds form impermeable barriers to the upward movement of water. The mud below the clay remains saturated, whereas the mud above the clay becomes relatively dehydrated and contracts laterally, leading eventually to plastic flow of the underlying material at right angles to the bedding and an interlocking texture marked by an argillaceous seam. Dunnington (1954) effectively countered the contraction-pressure theory of Shaub with his attribution of a pressure-solution origin in consolidated rocks to many stylolitic fabrics. The pressure-solution theory, in Dunnington's words, "recognizes that hard rock is removed during the formation of stylolites, that the removal takes place by solution, with deposition of insoluble residues *in situ*, and that the solution is localized and directionally controlled by pressure." Dunnington's case for the post-consolidation development of stylolites where calcite veins are displaced and shells are truncated seems incontrovertible. The pressure-solution theory had been advocated earlier by Stockdale (1922, 1926, 1943), and although the precise mechanism of the pressure-solution process is not always agreed on, the ease with which the theory seems to account for most aspects of stylolites has led to its general acceptance by western geologists. Petrofabric analysis of stylolitic rocks has also been interpreted as supporting the pressure-solution theory (W. W. M. Brown 1959). Nevertheless, the view that stylolites form in unconsolidated rocks retains advocates (Prokopovich 1952, Rybakov 1959).

The pressure-solution theory of stylolite formation can apply only to consolidated or compacted material. Strong consolidation implies lithification, but not necessarily cementation (the occupation of pores by secondary minerals). If pressure-solution in porous rock is followed by nearby precipitation, the rock becomes cemented. Thus Waldschmidt (1941), Sloss and Feray (1948), and Heald (1959) proposed pressure-solution as a cause of cementation in sandstones, and Barret (1964) and Park and Schot (1968) concluded that it plays the same role in limestones. Other authors (Conybeare 1949, 1950; Herbert and Young 1957) emphasized the lateness of stylolites in some diagenetic sequences, and Park and Schot (1968) have accepted the possibility that some stylolites form after cementation. The process probably tends to begin in porous rocks, causing cementation, and continues in some after the elimination of most pore space, expelling almost all subsequently dissolved material. In this way, both intrastratal and interstratal cementation may be caused by pressure-solution in limestones or sandstones. On the other hand, some stylolites seem to have begun growth in rocks of very low porosity, such as volcanic rock and primary chert.

The surfaces of stylolitic seams are uneven, but most are parallel in a general way to bedding, and the pressure required to form them is apparently due mainly to load. Each seam indicates a loss of section at least equal to its amplitude, though Pettijohn (1957) pointed out that the loss may be far greater. Published estimates of the minimum loss of section demonstrated in different units include 40% (Stockdale 1926), 25% (Weller 1960) and 37% (Park and Amstutz 1968). Weller has also suggested that many clay seams in limestones have formed by concentration of insolubles without formation of interlocking surfaces. Barrett (1964) assumed a like origin for sand and clay seams in Oligocene calcarenites with a consequent volume loss of 4-16%. It is not impossible that some limestone units have disappeared entirely because of pressure-solution, but prospects of demonstrating this in specific instances are slight.

Records of stylolites in limestone, dolostone, marble, sandstone and quartzite are numerous. Stylolites are also reported from chert (Trefethen 1947), shale and conglomerate (Bushinskiy 1961), chert-siderite rocks (James 1951), carbonate-fluorite rocks (Amstutz and Park 1967), phosphorite, bauxite, anhydrite (Bushinskiy 1961), gypsum (Stockdale 1936, Bushinskiy 1961), sylvite (Bushinskiy 1961, Holwerda and Hutchinson 1968), barite (unpublished references cited by Park and Schot 1968), pyrite, arsenopyrite, zircon, chromite and rutile (Schidlowski and Turrnit 1966), rhyolite (Bloss 1954, Golding and Conolly 1960, 1962), welded tuff (Burmah and Riley 1955), pegmatite and quartz lenses (Bailly 1954), and asbestos (Males and Golding 1961). Trurnit (1967), who has listed many minerals affected by pressure solution, has been able to arrange them in a sequence according to pressure-solubility. A few stylolites cut across bedding (Blake and Roy 1949, Prouty 1952, Rigby 1953, Young 1953, Edgell 1964, Plate 2, Fig. 6). It is evident that, although Shaub's contraction-pressure theory cannot be disproved for some stylolites, it cannot explain those in non-sedimentary rocks or those transverse to bedding.

Stylolites in Western Australian Rocks

Limestones

There is no doubt that detailed examination of many otherwise fairly homogeneous Western Australian limestones will reveal stylolitic seams of quartz, clay minerals, limonite, carbonaceous material, graphite, bituminous material or combinations of these substances, for they commonly represent the insoluble residue of limestones after pressure-solution. Stylolites of this kind have been noted in fine-grained calcitic limestone from the Proterozoic Mt McRae Formation (Fig. 1), in fine-grained dolostone from the Proterozoic Duck Creek Dolomite (both from the West Pilbara area), and in Devonian limestones from the Fitzroy Trough.

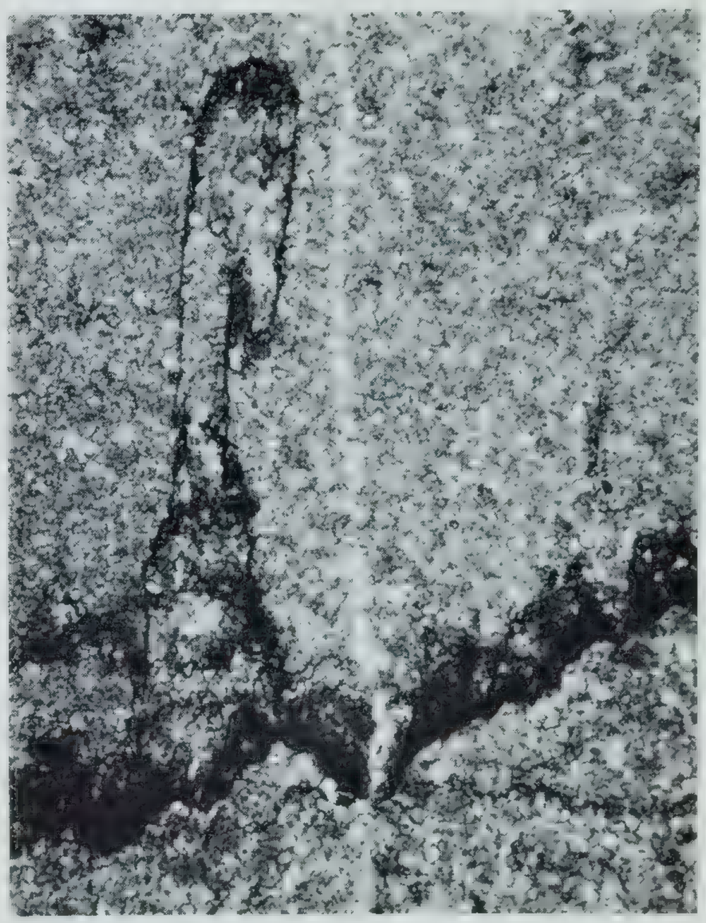

Figure 1.—Photomicrograph of stylolite in calcitic limestone from Proterozoic Mt McRae Formation, 386 feet 5 inches in core Y1, Yampire Gorge. The stylolite splits and coalesces, and is cut by a calcite vein. Plane polarized light. Width of field 2.5 mm.

More complex stylolites are likely to form in limestones containing two carbonate minerals, for one mineral may prove less soluble than the other, causing differential pressure-solution. For example, the fabric in parts of the Ordovician Thangoo Limestone from West Australian Petroleum's Roebuck Bay No. 1 Well in the Canning Basin, where dolomite caps most of the stylolite columns in the mainly calcitic limestone,

indicates differential pressure-solution of calcite with respect to dolomite (Fig. 2). We can speculate that relative enrichment of dolomitic limestone in dolomite could, in extreme cases, form dolostone from dolomitic limestone.

The Thangoo Limestone in Roebuck Bay No. 1 comprises micrites, intrasparites, and pelsparites, some of which are highly dolomitized, and fine-grained dolostones of uncertain origin. It has been suggested elsewhere (Glover 1968) that the 646 feet interval of Thangoo Limestone intersected in this well is the remains of a formation that has lost at least 130 feet, and perhaps far more, by pressure-solution.

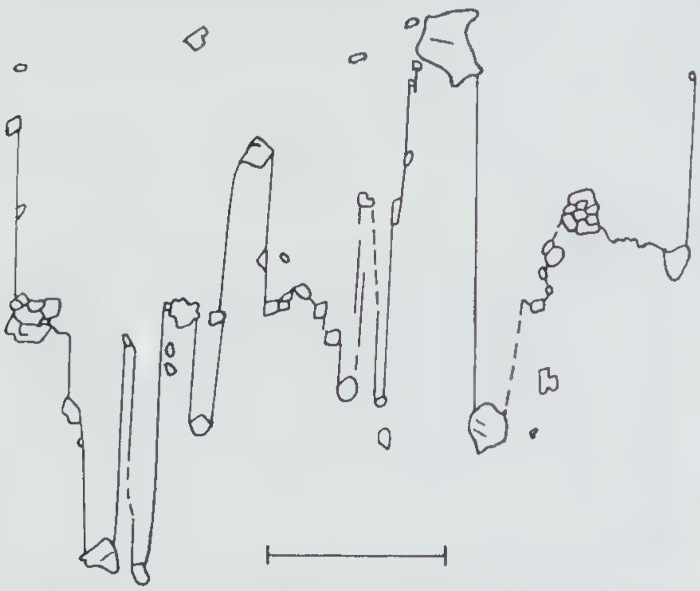

Figure 2.—Stylolite from intrasparite in Ordovician Thangoo Limestone, 3515-3522 feet, Roebuck Bay No. 1. Dolomite grains or aggregates occur at the ends of most columns, but are sparse elsewhere. A few grains show cleavage. Drawn to scale from thin section. The horizontal line represents 1 mm.

Stylolitic boundaries are fairly common between dolomitic and calcitic portions of Palaeozoic dolomitic limestones. Parts of the Thangoo Limestone in cores from West Australian Petroleum's Goldwyer No. 1 Well illustrate this feature. The bore-core in Figure 3 is made up of interbedded light grey, silty, fine-grained calcitic limestone bands of irregular thickness and thinner, dark grey, silty dolomite bands. Some black stylolitic seams of silty clay are found within the calcareous bands, but most seams form well-defined boundaries between the calcareous and dolomitic bands. A traverse along a thin section of the rock revealed 41 mm of silty calcitic limestone, 16 mm of silty dolomite, and 2 mm of silty clay. The concentration of quartz silt in the clay is about 15 times greater than in the calcitic limestone so that if the clay is a residue of the pressure-solution of calcite, it represents 30 mm of calcitic limestone. Thus, if this rock developed by differential pressure-solution of calcite in a consolidated limestone consisting of banded, silty, slightly argillaceous calcitic limestone, and dolomite, over 30% of its original length in the part sectioned was lost.

The possibility that some impurities promote solution in limestones must be borne in mind, for no simple, direct relationship between depth of burial and loss of volume by pressure-solution seems to have been established. Despite this uncertainty, it is evident from the literature and from the above examples, that section loss of 5-40% is not exceptional over small intervals. Losses of this order in thick limestone formations would have to be accommodated by buckling or collapse in formations above.

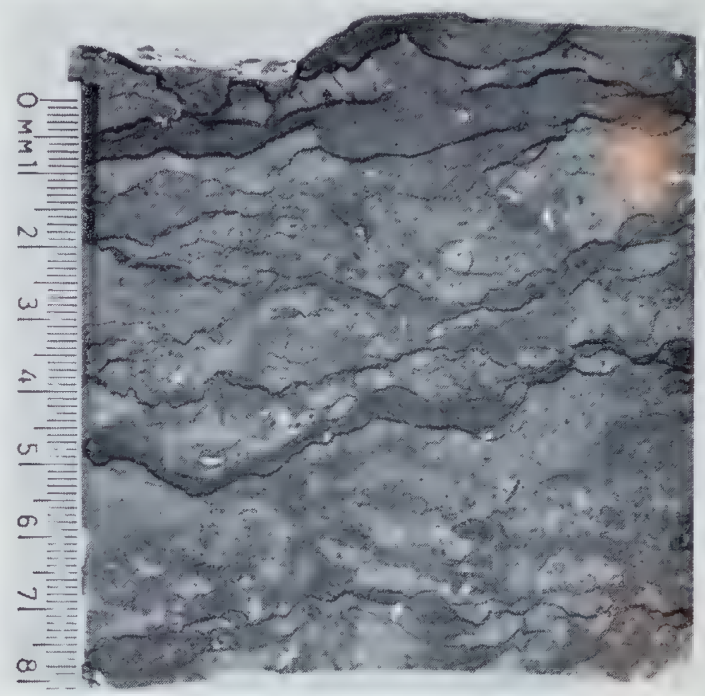

Figure 3.—Interbedded silty dolomite (dark grey) and silty calcitic limestone (light grey) in Ordovician Thangoo Limestone, 3613-3629 feet, Goldwyer No. 1. Black stylolitic seams commonly form boundaries between dolomite and calcite.

Sandstones

Macrostylolites are less common in sandstones and quartzites than in limestones, and appear to be associated with much smaller loss of section. They have been observed in Western Australian rocks but do not seem to have been recorded. In view of the numerous accounts of their occurrence in North America, it is unlikely that they are as rare here as the literature would suggest. The stylolite illustrated in Figure 4 has an amplitude of about four cm and is in a silicified medium-grained quartz sandstone or impure orthoquartzite containing intergranular patches of microcrystalline quartz and less common patches of limonitic clay. The clastic cores of many quartz grains are visible under the microscope. The stylolite seam is about one mm thick, is composed of white and red argillaceous material, and is approximately parallel to the bedding. The specimen is a boulder from the Upper Devonian Willaraddie Formation, near Gneudna Well, in the Carnarvon Basin.

It has been suggested on empirical grounds by Heald (1959) that the stress required to form stylolites in sandstones may not be especially high because the clay minerals, carbonaceous minerals and iron-bearing minerals constituting the stylolitic seams were originally partings in the rock and promoted the solution. Thomson (1959) proposed that clay seams can

Chert

Macrostylolites and microstylolites in the Coomberdale Chert were described and figured by Logan and Chase in 1956 in an unpublished B.Sc. Honours thesis in the Department of Geology, University of Western Australia. In a published account (Logan and Chase 1961) the stylolites were not mentioned, but it was demonstrated that the chert was a silicified limestone grading into dolomite and containing many relicts of limestone fabric including ooliths, carbonate rhombs, and fossils. It is not known if the stylolites are also relicts of the limestone fabric, or if they formed in the chert. A microstylolite from the Coomberdale Chert is illustrated in Figure 5.

Figure 4.—Stylolite in silicified medium-grained sandstone of the Upper Devonian Willaraddie Formation.

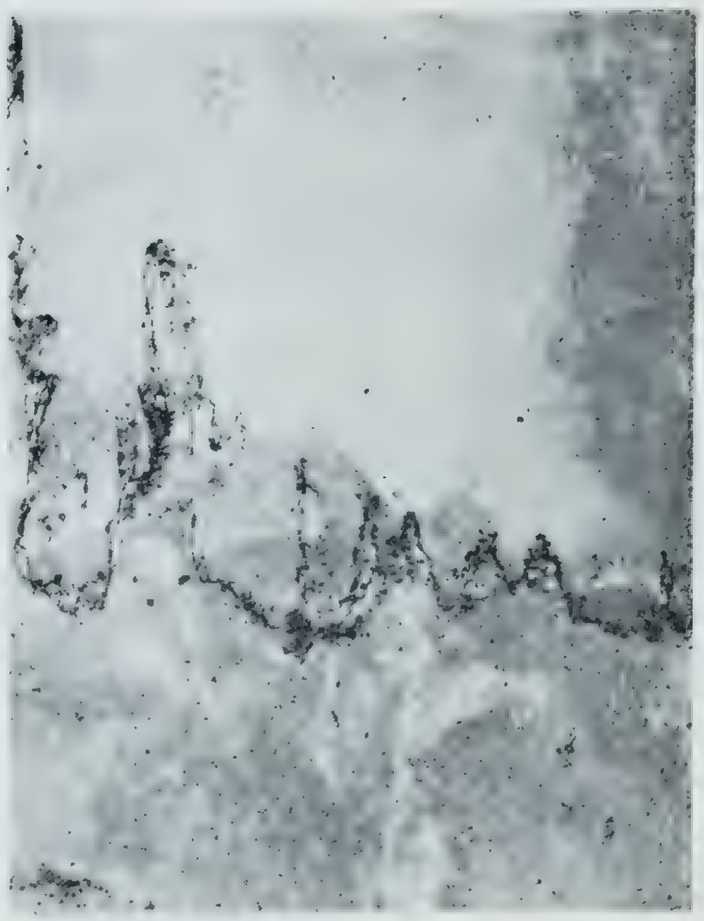

Figure 5.—Photomicrograph of stylolite in Coomberdale Chert (probably Proterozoic) from Kiaka Cliff, 9 miles north of Moora. Plane polarized light. Width of field 2.8 mm.

increase the pH of solutions and promote solution of silica and subsequently Lerbeckmo and Platt (1962) suggested a mechanism involving carbon and iron compounds in seams which could also locally increase pH. The lithology of the stylolitic quartzite described above is compatible with the hypotheses of Heald and Thomson.

Many standstones, otherwise regarded as potential reservoir beds for hydrocarbons in Western Australia, are tight because of silicification, and it is important to establish how they were silicified. Waldschmidt's studies of sandstones in the Rocky Mountains region (Waldschmidt 1941) indicated that pressure-solution caused interlocking boundaries between grains, and was accompanied by contemporaneous precipitation in adjacent pores. Heald (1956), after studying the Simpson and St Peter Sandstones, also accepted pressure-solution at grain contacts as the source of most dissolved silica, but assumed that precipitation was not necessarily local. There are sutured grain contacts in the Enokurra Sandstone (Glover 1963), but they are rare in other silicified sandstones examined to date. Most quartz cement in bore-cores of silicified standstone has not been derived *in situ*, and the contribution of pressure-solution to its origin can only be assessed by comprehensive lateral studies of formations. Some solution and precipitation is likely to be practically independent of pressure, being due rather to changes in pH of circulating waters, or to other influences. The magnitude of silicification in replacement cherts, for example, seems to exclude pressure-solution as the only source of precipitated silica. The literature on silicification is extensive and will not be reviewed here: a recent summary has been presented by Fairbridge (1967).

Cherty, iron-rich rocks

A stylolite from the S11 macroband of the Dales Gorge Member of the Brockman Iron Formation at a depth of 385 feet 6 inches in bore-hole 51 is illustrated in Figure 6 (bore-hole 51 is shown on the geological map of Wittenoom Gorge, which is Plate 6 of *Geol. Surv. W. Aust. Bull.* **119**). The stylolite has an amplitude of about one centimetre, and separates banded chert-stilpnomelane rock containing siderite and accessory pyrite from siderite rock, also containing accessory pyrite. Black material of uncertain composition is concentrated along the stylolite in the siderite rock, and pyrite is more abundant in the dark area. This stylolite resembles those described by

James (1951) in chert-siderite rocks of the iron formation from Michigan, where they make up part of the fabric from which a primary origin for the chert has been inferred.

Figure 6.—Photomicrograph of part of S11 macroband of Dales Gorge Member, 385 feet 6 inches, bore-hole 51. Stylolite between dark impure siderite (top) and white siderite in banded siderite-chert-stilpnomelane rock (bottom). White lenses in grey, flaky stilpnomelane are chert. Plane polarized light. Width of field 1.7 mm.

Contorted seams or microstructures from the S13 macroband of the Dales Gorge Member at 318 feet 5 inches in bore-hole 51 are shown in Figure 7. These seams consist of chert, stilpnomelane and siderite, with a concentration of siderite along their margins, and form irregular boundaries with the otherwise euhedral ankerite crystals in the surrounding chert. Their undulose form, and the way in which they cut ankerite grains, suggest that they are at least partly due to pressure-solution. If the chert is primary the seams may represent thin layers of impurity which have promoted pressure-solution in the way envisaged for quartzites by Thompson (1959) and Lerbeckmo and Platt (1962). If the chert has replaced limestone, the seams could be relict stylolites, for which a rather complex sequence may be invoked, as follows:

(1) formation of impure limestone containing replacement euhedra of siderite and ankerite.

(2) differential pressure-solution of calcite concentrating iron-rich carbonates along the seams, and partly dissolving ankerite.

(3) preferential silicification of calcite, preceded or followed by reconstitution of impurities to stilpnomelane.

A vertical stylolite has been figured in a siliceous discoidal body interpreted by Edgell as the silicified alga *Collenia brockmani* n. sp., in the Brockman Iron Formation (Edgell 1964, Plate 2, Fig. 6). The stylolite was presumably formed by lateral pressure, but the exact mechanism of its origin is obscure.

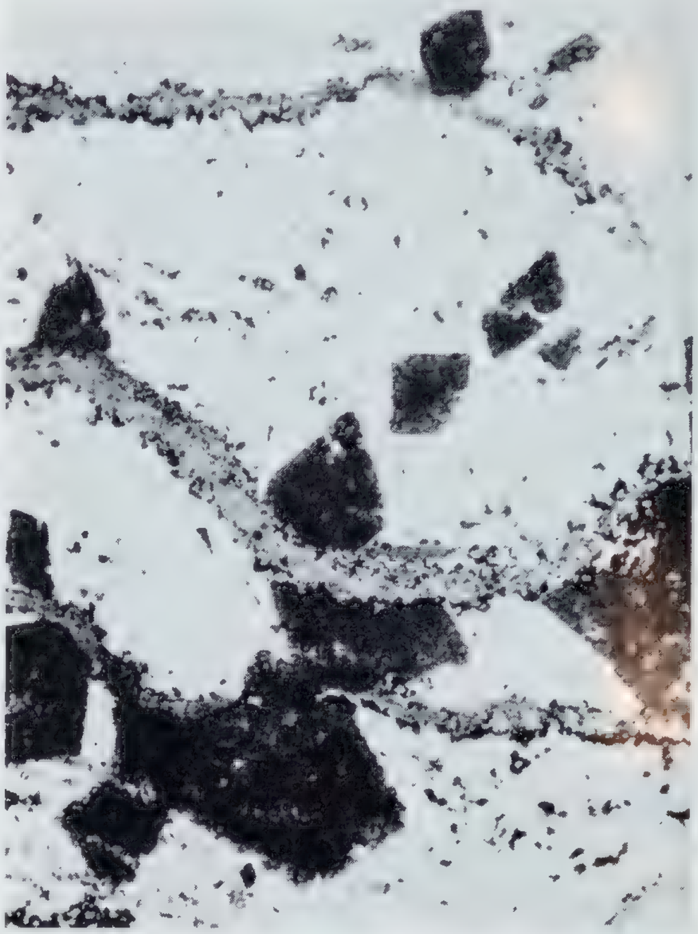

Figure 7.—Photomicrograph of part of S13 macroband of Dales Gorge Member, 318 feet 5 inches, bore-hole 51. Large dark grains are ankerite, small dark grains are siderite, white areas are chert. Grey seams, apparently of stylolitic origin, consist of chert and stilpnomelane, with siderite concentrated along margins. Plane polarized light. Width of field 2.1 mm.

Conclusions

Stylolites are not uncommon in limestones, and their formation can cause significant loss of section, changes in lithology and possibly changes in the structure of overlying rocks. Their potential influence should be borne in mind during detailed surveys of limestone areas. On the other hand, although stylolites as known in sandstones and quartzites, there has been no compelling evidence that most of the silicification of sandstones in Western Australia, with its adverse effect on their petroleum prospects, has been related to pressure-solution. Stylolites have also been recorded in chert and iron-rich cherty rocks of complex lithology, and preliminary examination suggests that these petrogenetically significant phenomena will be reported more frequently. However, there

seem at present to be few effective criteria for deciding if stylolites in replacement cherts are relict limestone structures.

Acknowledgements

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5.—Endemism in the Western Australian flora at the species level

by J. S. Beard*

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Abstract

An analysis is given of endemism in the 5802 recorded species of flowering plants from Western Australia. Within the three floral provinces of the state the percentages of endemism at the species level are: Southwestern 79, Northern 77, Eremaean 45. The equivalent percentages for the whole flora of each province when distribution outside the state of Western Australia is taken into account are 86, 30 and 62. Data on constituent families and genera are tabulated.

The distribution of the Australian flora was analysed by Burbidge (1960) at the generic level and it was shown that of the 462 genera represented in the Southwestern Botanical Province of Western Australia 111 are restricted thereto. No similar figures at the species level have been presented in recent years, and in the absence of a published critical Flora of Western Australia it is not easy to do so.

Locality data included by Beard (1965) in the *Descriptive Catalogue of West Australian Plants* afford however a useful basis for calculations. The catalogue lists all the known published species of flowering plants believed to be valid and native to Western Australia to the number of 5312, omitting the grasses and sedges. The distribution of each species is shown in terms of the botanical provinces and districts of Gardner and Bennetts (1956). Similar data on the Gramineae are available in Gardner (1952) where there are 278 native species, and data on 212 species of Cyperaceae have been separately compiled on the basis of those species listed in Gardner (1930).

The range of most species is still imperfectly known, but on the basis of existing knowledge the following figures relate to species distribution within Western Australia itself.

Northern Province only	1117 species
Northern and Eremaean	263
Northern and Southwestern	22
All provinces	43
Total Northern	1445 species
Eremaean Province only	811 species
Northern and Eremaean	263
Southwestern and Eremaean	705
All provinces	43
Total Eremaean	1822 species
Southwestern Province only	2841 species
Southwestern and Eremaean	705
Northern and Southwestern	22
All provinces	43
Total Southwestern	3611 species
TOTAL ALL SPECIES	5802

* King's Park and Botanic Garden, Perth, Western Australia.

As mentioned above, these figures relate only to the distribution within the state of Western Australia as a political rather than a phytogeographical unit. The Northern and Eremaean Provinces in fact extend across the continent and correspond with the Tropical Zone and Eremaean Zone of Burbidge (1960). Their species can be expected to have a trans-Australian distribution. The Southwestern Province is isolated by 1000 miles from any comparable area in the east and is generally believed to contain a high proportion of endemic species.

Discussing the data first on a purely Western Australian basis, it will be seen that only 43 species are known to occur throughout the state, while a further 22 have a northern and southern distribution. The Southwestern Province has by far the richest flora, two-thirds of the total. One-fifth of the Southwestern species occurs also in the Eremaea. The Northern flora is surprisingly small but this may only be due to lack of knowledge and incomplete collecting. Seventy-nine per cent of the Southwestern flora is restricted to that Province, seventy-seven per cent in the case of the Northern, and only forty-five per cent in the case of the Eremaean.

The concept of Botanical Provinces, on which this analysis has been based, is of course purely subjective and there may be those who doubt the reality of it. In cold fact it will be clear that concentrations of species can be expected in the higher rainfall areas of the extreme north and south-west. Arbitrary provincial boundaries based on bioclimatic lines or on plant communities are a convenient means of giving expression to this, and are found to be effective in that 77 per cent of the northern flora and 79 per cent of the southwestern are confined within the chosen provincial boundaries.

The above data do not afford an estimate of true endemism in the Southwestern Province since many species listed as Southwestern on the ground that they do not enter the Eremaea are in fact found elsewhere in Temperate Australia. Further data on species distribution was therefore sought by consulting the authors cited in the References. The wider distribution of the West Australian species thus obtained is given in Table 1, where *Endemic* means confined to Western Australia, *E/Aust.* means occurring in Eastern Australia, *A/Asia* means extending to New Guinea, New Caledonia and New Zealand, and *Cosmo* (cosmopolitan) means having any wider distribution than Australasia.

Table 1

Wider distribution of Western Australian plant species

	Endemic	E/Aust.	A/Asia	Cosmo.	Total
Provincial Distribution—					
Northern only	355	610	72	80	1117
Northern and Eremaean	64	167	12	20	263
Northern and Southern	11	34	10	10	65
Total N.P.	430	811	94	110	1445
Eremaean only	532	259	11	9	811
Northern and Eremaean	64	167	12	20	263
Southwestern and Eremaean	519	177	5	4	705
All Provinces	7	25	5	6	43
Total E.P.	1122	628	33	39	1822
Southwestern only	2472	280	61	28	2841
Southwestern and Eremaean	519	177	5	4	705
Northern and Southern	11	34	10	10	65
Total S.W.P.	3002	491	76	42	3611

From Table 1 the following percentages of endemism can be calculated:

	%
Northern Province:	
whole northern flora	30
plants solely northern	32
Eremaean Province:	
whole eremaean flora	62
plants solely eremaean	66
Southwestern Province:	
whole southwest flora	86
plants solely southwestern	87

It is to be expected that most species of northern Australia range across the continent, and the proportion confined to the Kimberley District of Western Australia is on the other hand unexpectedly large and it is hard to know whether this conclusion is affected by inadequate information. The southwestern flora, as expected, gives a very high figure and it becomes clear that it is effectively distinct not only from that of the other provinces within Western Australia but from that of South-eastern Australia as well. The reasons for this state of affairs are being discussed in another paper.

It is of interest to compare similar figures given by East in 1912:

> "A consideration of the data at present available for the whole state seems to justify the following estimate of the species more or less restricted to each division and constituting the present flora of the state:—
>
> South-west division 2,239 species, of which 2,013 are endemic; Eremian or central division, 706 species of which 614 are endemic; north or Kimberley division, 1,221 species of which 780 are endemic. Totals 4,166 species of which 3,407 are endemic."

The proportions are much the same but the totals have risen since 1912, showing the advance in botanical knowledge in half a century. In other respects there has been less progress, as witness this further quotation from East which speaks for itself:

> "It is a matter of great regret that successive Governments have so long neglected to develop the scientific knowledge of the flora of the state. All the other states have compiled and published floras, but that for Western Australia has yet to be written."

Numerical data on certain important families and genera follow.

For assistance in preparing this paper the author is indebted to Mrs. P. Fairall and to Geh Thuan Hsien, who searched the literature mentioned.

Data on selected families

E. Endemic species
O. Others
% Percent endemism

Chenopodiaceae:

Northern:	E. 5	Eremaean:	27	Southwestern:	14
	O. 16		53		20
	% 24		34		41

Compositae:

Northern:	E. 13	Eremaean:	83	Southwestern:	102
	O. 49		94		78
	% 21		47		57

Euphorbiaceae:

Northern:	E. 15	Eremaean:	18	Southwestern:	35
	O. 34		17		11
	% 33		52		76

Gramineae:

Northern:	E. 77	Eremaean:	26	Southwestern	30
	O. 96		80		56
	% 45		25		35

Liliaceae:

Northern:	E. 4	Eremaean:	16	Southwestern:	77
	O. 7		14		18
	% 36		54		81

Mimosaceae:

Northern:	E. 27	Eremaean:	96	Southwestern:	158
	O. 49		29		10
	% 35		77		94

Orchidaceae:

Northern:	E. —	Eremaean:	4	Southwestern	101
	O. —		6		42
	% 0		40		70

Papilionaceae:

Northern:	E. 27	Eremaean:	97	Southwestern:	290
	O. 78		41		25
	% 26		70		92

Data on selected genera

Acacia:

Northern:	E. 24	Eremaean:	95	Southwestern	156
	O. 46		31		12
	% 34		76		94

Boronia:

Northern:	E. 1	Eremaean:	6	Southwestern:	28
	O. 2		1		2
	% 33		86		93

Daviesia:

	Northern:	Eremaean:	Southwestern:
E.	2	15	40
O.	1	1	4
%	67	94	91

Drosera:

	Northern:	Eremaean:	Southwestern:
E.	1	3	34
O.	3	2	2
%	25	60	94

Eremophila:

	Northern:	Eremaean:	Southwestern:
E.	1	51	15
O.	3	18	6
%	25	84	72

Eucalyptus:

	Northern:	Eremaean:	Southwestern:
E.	12	43	65
O.	27	19	9
%	31	69	88

Goodenia:

	Northern:	Eremaean:	Southwestern:
E.	5	23	23
O.	10	8	7
%	33	74	77

Helipterum:

	Northern:	Eremaean:	Southwestern:
E.	2	19	10
O.	1	17	10
%	67	53	50

Leucopogon:

	Northern:	Eremaean:	Southwestern:
E.	—	10	97
O.	—	—	4
%	—	100	96

Pimelea:

	Northern	Eremaean:	Southwestern:
E.	—	14	24
O.	5	3	3
%	—	82	90

Stylidium:

	Northern:	Eremaean:	Southwestern:
E.	2	14	80
O.	10	—	5
%	17	100	94

Thysanotus:

	Northern:	Eremaean:	Southwestern:
E.	—	1	20
O.	2	1	3
%	O	50	87

Summation of genera cited

Genera	Northern Province		Eremaean Province		Southwestern Province	
	E.	O.	E.	O.	E.	O.
Acacia	24	46	95	31	156	12
Boronia	1	2	6	1	28	2
Daviesia	2	1	15	1	40	4
Drosera	1	3	3	2	34	2
Eremophila	1	3	51	18	15	6
Eucalyptus	12	27	43	19	65	9
Goodenia	5	10	23	8	23	7
Helipterum	2	1	19	17	10	10
Leucopogon	—	—	10	—	97	4
Pimelea	—	5	14	3	24	3
Stylidium	2	10	14	—	80	5
Thysanotus	—	2	1	1	20	3
TOTALS	50	110	294	101	592	67
% Endemism	32		75		90	

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6.—Conodont and fish remains from the Gneudna Formation, Carnarvon Basin, Western Australia

by George Seddon*

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Abstract

Eight species of conodont and fish remains which include dipnoan palatal plates are described from the Gneudna Formation, Carnarvon Basin, Western Australia. The evidence for age determination and correlation with the Canning Basin is reviewed; with the conclusion that the Gneudna Formation probably represents a relatively short interval of time at the Middle/Late Devonian boundary, and is correlative with a part of the Sadler Formation in the Canning Basin.

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Introduction: the problem

The Devonian fauna from the Carnarvon Basin and its supposed correlatives in the Canning (Fitzroy) Basin are strikingly different in two respects: the Gneudna Formation is rich in individuals but consistently poor in species, whereas the faunas of the Sadler, Gogo and Virgin Hills Formations are richly varied. Moreover, the taxonomic units do not correspond; in fact, of the 18 species that have been named from the Gneudna Formation, only one (*Spinatrypa aspera prideri* (Coleman)) has hitherto been recorded without reservation from the Canning Basin. Most of the species and subspecies described from the Gneudna Formation are endemic to it ("endemic" here equals: recorded only from that formation), as follows:

1. *Nautiloids* (Collins, 1966)

Bulletoceras variabile Collins, with 19 variants. Endemic

Bulletoceras radiatum Collins, with 19 variants. Endemic

These two species belong to the same phylogenetic lineage, and there are transitional forms. The former dominates the lower, and the latter, the upper part of the formation.

Michelinoceras sp. c Collins (a single fragment)

Both *genera* are present in the Canning Basin, and *Bulletoceras* is not known outside Western Australia.

2. *Ostracods* (Jones, 1962)

Cryptophyllus sp. a Jones

This species has been doubtfully recorded from the Frome Rocks Well No. 2, in the Canning Basin, from the *Avonia proteus* zone of Famennian age, but not from the Frasnian formations of the Canning Basin. The genus is cosmopolitan.

3. *Corals* (Hill, 1954)

Disphyllum virgatum (Hinde) var. *variabile* Hill

The *variety* is endemic; the species is cosmopolitan, and is characteristic of the Givetian and Frasnian in Europe. *D. virgatum* var. *densum* Hill is recorded from the Pillara Limestone, Canning Basin.

Hexagonaria gneudnensis Hill. Endemic; closely related to *H. brevilamellata* (Hill) from the basal parts of the Pillara Limestone.

Thamnopora cf *polyforata* (Schlotheim).

T. polyforata s.s. is cosmopolitan and is characteristic of the Upper Givetian and lower Frasnian of Belgium. Neither the species nor the compared species has been recorded from the Canning Basin.

Alveolites caudatus Hill — Endemic

4. *Brachiopods* (Coleman, 1951)

Spinatrypa aspera prideri (Coleman): present in the Canning Basin "at Sadler Ridge in the Upper Frasnian *torrida* zone, and probably in the Upper Famennian *proteus* zone in the Geikie Gap area" (Veevers, 1959b, p.20).

(Glenister, 1956)

Austrospirifer variabilis Glenister — Endemic

Cyrtospirifer minilyaensis Glenister — Endemic

Cyrtospirifer australis Glenister — Endemic

Cyrtospirifer gneudnaensis Glenister — Endemic

Cyrtospirifer brevicardinis Glenister — Endemic

Glenister made no comparison between these and other members of the genus.

(Veevers, 1959a, b)

Productella occidua Veevers — Endemic?

Camarotoechia puteana Veevers — Endemic

closely related to *C. congregata* from the upper Givetian and lower Frasnian of New York State.

Spiriferidae gen. et sp. ind. — Endemic

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cf *Ladjia saltica* Veevers. *L. saltica* Veevers ss. is the name bearer of a zone, which Veevers considers to be mid-Frasnian, in the Canning Basin.

5. *Spores* (Balme, 1960)

Balme described 8 species, three of which are new, from the Pelican Hill bore, from sediments correlated with the Gneudna Formation. The endemic species, especially *Geminospora lemurata* are 'overwhelmingly the most abundant.' (p.5). The remaining species . . . can be closely matched with forms occurring in the Givetian and Frasnian deposits in Russia, West Europe or North America' (p.9). But he notes 'the complete dissimilarity from rich Famennian assemblages known from many localities in the Fitzroy Basin' (p.9). There is no account of Frasnian assemblages from the Canning Basin.

Conclusion. Although the Gneudna species are often closely related to species from the Devonian of the Kimberley region, they are nevertheless distinct, and there has hitherto been only one unequivocal claim to taxonomic identity. Others may be established, and further work should be directed towards testing the *tentative* claims. For example, Veevers (1959b, p.26) notes a possible (single specimen) occurrence of *Productella occidua* from the Sadler Formation. The present author, in company with the three Honours students from the University of Western Australia, found a thin band of oncoceratid nautiloids about 30 ft. below the top of the formation at the type locality. These may be referable to *Clavigeroceras suzanni* Collins, described from a mid-Frasnian section of the Virgin Hills Formation (Hosemann, p.133 in Alcock, Hosemann and Read, 1966). Veevers (1959b, p.30) records three specimens of cf. *Ladjia saltica* Veevers from the Gneudna Formation. The Honours students referred to above failed to find further specimens (Hosemann, p.132 in Alcock, Hosemann and Read, 1966).

However it is clear from the data presented above that additional work on the Gneudna fauna over the years has given a cumulative emphasis to its taxonomic distinctness rather than the reverse, and this requires explanation.

Hill (1954, p.8) provisionally correlated the Gneudna Formation with the lower part of the Pillara Limestone of Givetian age and concluded that "differences in species between the two limestones may be due to differences in province between the Carnarvon and Kimberley regions". Two things can be said about this supposition. The first is that these two regions do not today represent two marine provinces; they both fall within the Dampierian Province of Hedley, 1926. The second is that even if they did (if, for instance, we were comparing the shelf fauna off Broome with that from Cockburn Sound), there would be a high degree of overlap, with many common species. For example, of 99 species of foraminifera recorded from Western Australia, 31 show a preference for tropical and subtropical waters and 18 for temperate waters, but the other half show little latitudinal preference (Betjeman, 1965, p.49-52). Of some 290 species of echinoderms recorded from the Dampierian province, only 40 are not also found along the more southern coasts (Clark, 1946, p. 467). Ekman (1953, p.202) adds palaeontological data, and concludes: "we may say with reference to the sea-urchins, and in all probability also the greater part of the South Australian shelf fauna, a weak affinity with the rest of the temperate southern fauna and a considerably closer affinity with the tropical fauna was a characteristic feature at all geological periods from the Cretaceous inclusive".

Poverty of the Gneudna fauna. Balme (1960, p.1) writes of "Microfloras rich in individuals but poor in species." Collins (1966, p.iii) notes that "the rich and diverse Fitzroy Basin fauna includes 17 orthocerid, 10 discosorid, 9 oncocerid and 4 bactritid spp. referable to 18 genera. In contrast, the numerous representatives from the Carnarvon Basin comprise only 2 discosorid and 1 orthocerid species referable to 2 genera." The brachiopod and coral assemblages are also rich in individuals and poor in species. Collins (1966, p.26) concludes that "the rich and varied nautiloid and bactritid assemblages of the Fitzroy Basin are a reflection of the great variety of ecological niches provided by a large reef complex. Similarly, the large numbers of few species in the Gneudna Formation is a reflection of the rather uniform environment of the open shelf." This may very well be the case, but ecological comparisons have no value until correlation is firm. This is apparent if we compare the Gneudna nautiloid faunule, not with the "rich and diverse Fitzroy Basin fauna" but with that of the Sadler Formation, from which Collins reports only six species of nautiloid and two bactritids (p.14). The age of the Gneudna Formation is relevant to the apparent poverty of the fauna in two ways: the first is that it may represent a relatively short interval of time: much of the apparent richness of the

Table 1

Conodonts from the Gneudna Formation

	G 8–9	G 10	G 12	G 12c	G 13	G 14	G 14+
Angulodus sp.		1					
Bryantodus. sp.	1						
Hindeodella subtilis		10		6			
Icriodus nodosus		3	1	8	4		1
Ozarkodina immersa		1			2		
Pelekysgnathus ? sp.	1						
Polygnathus pennatus		4		9	10	1	
Synprioniodina sp. cf. *S. prona?*		1					
Synprioniodina sp. cf. *S. prona*					3		

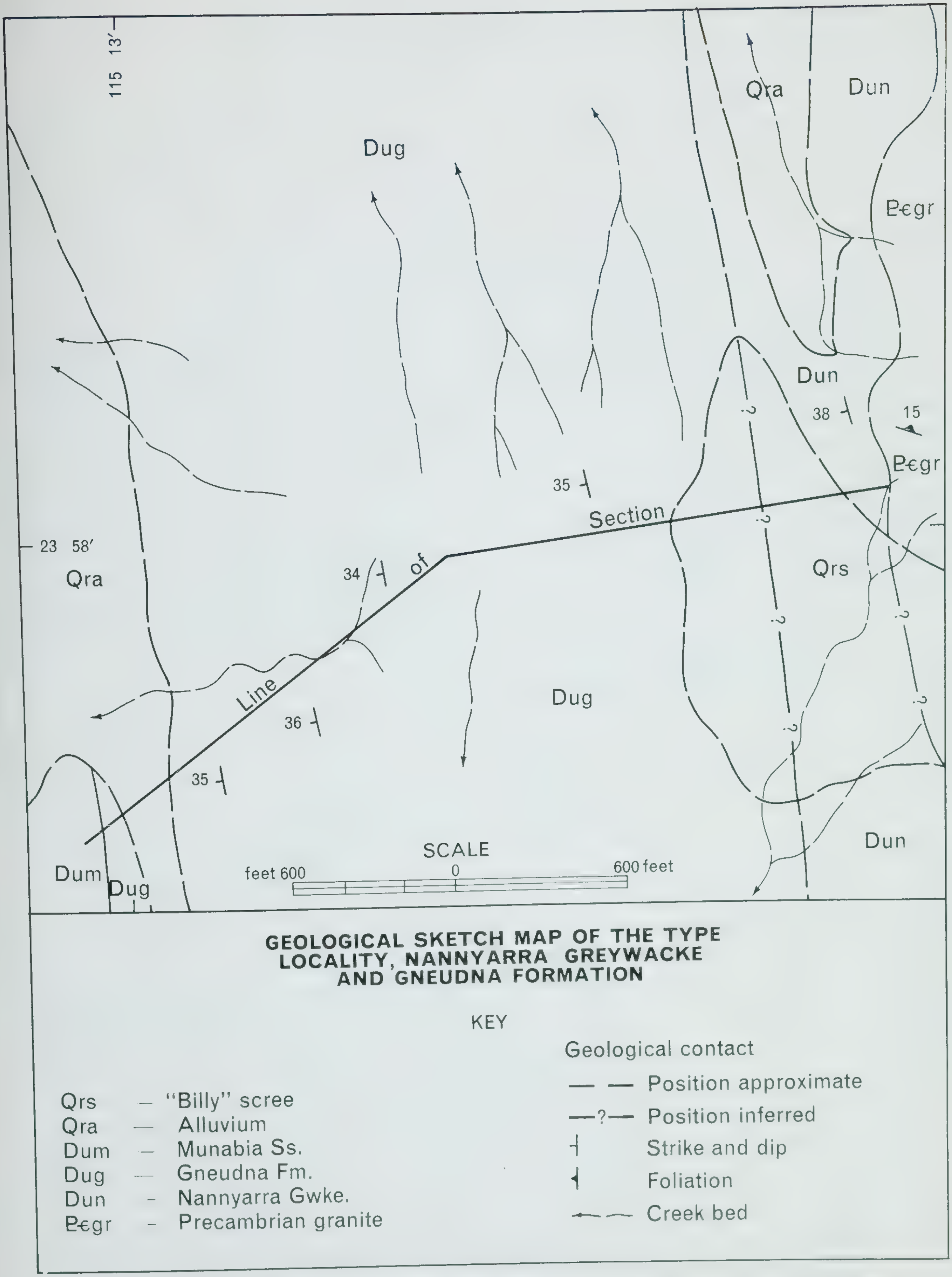

Figure 1.—Location of the sampled section. Map redrawn from Alcock, Hosemann and Read (1966).

Table 2

Fish remains from the Gneudna Formation

	4	7+	8p	8 9	9	9c	10	12	12c	13	13e	14	14+	15	cc12	cc14
Fish teeth, type a										+	+					
Fish teeth, type b	+			A			+									
Fish teeth, type c						+				+						
Conical teeth, type d				A	A		A	A	A	A			+	+	+	
Fish teeth, type e			+	+												
Rhomboid scales				A	A			A	A	A	A					
Fin scales (?)					A					A						
Bone fragments				+	A			+		A			+	+		+
Dipterus plates		+								+						

Notes: + = present in sample ; A = very abundant.

Nos. 4-15 are from the type locality of the Gneudna Formation.

. cc12 and cc13 are cores from Cape Cuvier 1 at 1,423 ft. and 1,480 ft.

Canning Basin fauna comes from the relatively condensed sequences. The second is that, with some exceptions, Upper Devonian faunas are more diverse than Middle Devonian ones (this is strikingly true of the conodonts).

Conodont and fish evidence

Conodonts were first reported from the Gneudna Formation by Glenister (McWhae and others, 1958, p.43). Specimens of *Icriodus* and *Polygnathus* were noted, but not described or illustrated. The present study was undertaken with the expectation of achieving both regional and intercontinental correlation through conodonts, but the results do little more than underline the problems already discussed.

Sampling. The formation was sampled at the type locality south-east of Williambury Homestead (Figure 1) along a section plane-tabled by Alcock, Hosemann and Read (1966). 28 bulk samples of 5-10 lb of rock were taken at approximately 50-foot intervals across some 1400 feet of section (see Table 3). The most distinctive feature of the Gneudna Formation in outcrop is the alternation of low ridges of medium-hard crystalline limestone with shallow troughs underlain by more friable rocks, mostly quartzwacke and calcarenite, with some siltstone. The samples represent most of the ridge limestones.

Three of the samples consisted of bulk collections of nautiloids, which are very abundant at certain stratigraphic horizons. (Nautiloids and conodonts are almost invariably associated in the Upper Devonian of the Canning Basin.) The samples from the type locality were supplemented by 6 core samples from Quail No. 1 and Cape Cuvier No. 1, drilled by West Australian Petroleum Pty. Ltd.

No conodonts were recovered from the core samples. Seven samples from the type locality yielded a total of 67 conodonts; the

Table 3

Locality data and notes

1	2
Munabia Sandstone	
G16a+	1820
G16a	1810
G15b	1645
G15	1590
G14+	1502
G14	1480
G13+	1345
G13	1326
G12c	1245
G12	1188
G11	1128
G10c	1085
G10	1052
G9g	1016
G9c	968
G9	925
G8	807
G7g	762
G7	656
G6	551
G5	495
G4	466
G3a	442
G2	408
Nannyarra Greywacke	
Precambrian	

A. The base and the top of the Nanyarra Greywacke-Gneudna Formation section may be located on aerial photographs, Winning Pool, W.A. 837, run 17, 5242 and 5243 by the following coordinates, measured in inches from the western and northern edges of the photographs.

		Top	Base
5242	W - E	2.06	2.96
	N - S	3.34	2.84
5243	W - E	5.78	6.68
	N - S	3.30	2.80

The line of section from the base bears 262° for 1,550 feet (100 feet past the small valley at the crest of the ridge): then bears 240° to the end of the section at the base of the Munabia Sandstone.

Bench marks have been painted on outcropping limestone bands at 495, 550, 660, 800, 1,330, 1,480, 1,530, 1,600 and 1,755 feet stratigraphically above the base of the section. A uniform dip of 35° W was assumed in computing the stratigraphic thickness. The column at the left shows the field no's (1) and the height in feet above the Precambrian contact (2). For a rock description of the sampled intervals, see Hosemann, in Alcock, Read and Hosemann, 1966, pp. 141-144.

B. In addition to the above, three bulk nautiloid collections from the type locality were processed for conodonts.

1. Sample no. 58048: 460-470 feet above the Precambrian contact, about G4
2. Sample no. 58067: 792-1020 feet, about G8-G9
3. Sample no. 58085: 1795-1810 feet, about G16A

C. Cores from Quail 1 and Cape Cuvier 1 (by courtesy of West Australian Petroleum Pty. Ltd.)

Well	Core No.	Interval Cored	Depth of Sample
Quail 1.	15	9163-9173	9168
	16	9741-9751	9742
Cape Cuvier 1.	12	1411-1416	1413
	13	1471-1476	1475
	14	1476-1484	1480
	15	1489-1494	1493

stratigraphic interval represented runs from 807 to 1502 feet above the Precambrian contact (Table 1).

Fish remains were recovered from the Cape Cuvier core at 1413 feet and 1480 feet and from 466 to 1590 feet above the Precambrian contact at the type locality.

Age and correlation. The conodont faunule is simple, consisting of 8 species, only two of which, *Icriodus nodosus* and *Polygnathus pennatus* s.l. are abundant. Although it is certainly either late Givetian or Frasnian, it is not clear which. The conodont species in the Gneudna Formation have been widely recorded from the Frasnian, but commonly in association with a large number of highly restricted, characteristically Upper Devonian forms (the ancyro- and palmatolepid-groups). The simplicity of the fauna is more characteristic of the Givetian, but Givetian indices are also lacking.

The dipnoan plates from the Gneudna Formation are probably referable to *Dipterus digitatus* Eastman, first described from the State Quarry Limestone of Iowa, which has long been regarded as basal Upper Devonian (Cooper and others, 1942, p.1783), chiefly on its brachiopod faunule. The State Quarry Limestone was sampled in detail for conodonts by A. R. Ormiston and A. B. Shaw in 1965. Faunas are characterized by *Icriodus nodosus, Polygnathus decorosus* s.l. (roughly synonymous with *P. pennatus* s.l.), and *Spathognathodus insitus* (Stauffer). The latter species is known only from the Lower and Middle *Polygnathus asymmetricus* zone, Upper Devonian, *to I*α in Alberta and Montana (Glenister and Rexroad, 1968, pp.6-12).

Icriodus nodosus and *Polygnathus decorosus* s.l. also occur throughout the underlying Givetian) Cedar Valley Limestone in Iowa, as they do in many other Givetian sequences, but usually in association with distinctive Middle Devonian forms. However, in the Coralville (uppermost) Member of the Cedar Valley Limestone, these two species dominate the conodont faunule, and in the *Straparollus* zone, the uppermost biotic unit of the Coralville Member, there is also a dipnoan, *Dipterus calvini*, which is directly ancestral to *D. digitatus*. It is probable therefore that the Gneudna fauna indicates an age very near the Middle/Upper Devonian boundary.

The conclusion that the Gneudna Formation is of latest Givetian and/or earliest Frasnian (lower to Iα) age returns to that of Hill (1954), but differs from that of Veevers (1959b, p.23) who estimates that the lower half is "probably Middle Frasnian, the upper half probably upper Frasnian". However this estimate arises from Veevers' correlation of the Gneudna Formation with the *saltica* and *torrida* zones of the Sadler Formation in the Canning Basin, which he considers to be middle and upper Frasnian respectively. The apparent conflict of evidence disappears if it is recognized that the Sadler Formation is not middle and upper Frasnian; it rather is latest Givetian and early Frasnian, and does not range beyond *to I*α. This is clear both from Glenister and Klapper's (1966, text-fig.2) conodont work, and from extensive re-sampling by myself. The conodont faunule can be referred to internationally recognized zones, and there can be no serious doubts about this correlation. The brachiopods, on the other hand, are mostly endemic at the specific level. Once it is recognized that the Sadler Formation is not younger than earliest Frasnian, the evidence for correlation between the Gneudna Formation and the Sadler Formation becomes more coherent, as follows:

Spinatrypa aspera prideri (Coleman) is common to the Gneudna Formation and the Sadler Formation. The probable occurrence of *Ladjia saltica* in the Gneudna Formation and the possible occurrence of *Productella occidua* in the Sadler Formation tends to confirm the correlation. Both the Pillara Formation and the Sadler Formation are in part late Givetian, and thus the coral evidence is consistent. The conodonts *Icriodus nodosus* and *Polygnathus pennatus* s.l. are common in the Sadler Formation, although the Sadler Formation also has the *to I*α indices such as *Ancyrodella rotundiloba* in its upper part. The Gneudna conodonts, on the other hand, show no change over some 700 feet of section, and it is probable that the formation records a relatively short time interval, despite the stratigraphic thickness. This would then be a partial explanation both of the limited variety of the Gneudna fauna, and of the failure to match closely the total Sadler fauna, which would represent a longer time interval. However, it should be emphasized that the differences remain striking: one not yet noted is that although nautiloids are plentiful in all three formations goniatites are not known from the Gneudna Formation, although they are superabundant in the Sadler and Gogo Formations. This and the other differences discussed are still in need of credible explanation.

Systematic palaeontology

Genus ANGULODUS Huddle, 1934

Angulodus sp.

Plate 1, figure 7

Remarks: The specimen figured lacks a main cusp. In other respects it accords well with Huddle's (1968, p.8) redescription of *A. pergracilis* (Ulrich & Bassler).

The denticles of the posterior bar alternate in size: those of the anterior bar are subequal. The anterior bar is deflected downwards and inwards. The bar is heavy, but is not laterally compressed.

Locality: one specimen, from G 13.

Repository: figured specimen (UWA 62136).

Genus HINDEODELLA Bassler, 1925

Hindeodella subtilis Bassler, 1925

Remarks: Several almost complete, and a number of broken, specimens are in good accord with Huddle's (1968, p.17) redescription of this species.

Locality: 7 specimens from G 10; fragments in G 12c.


1a
1b
1c
2a
2b
2c
3a
3b
3c
4a
4b
4c
5
6a
6b
6c
7
8
9
10
11
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Genus ICRIODUS Branson & Mehl, 1938

Icriodus nodosus (Huddle), 1934

Plate 1, figures 4a, b, c; 5, 6a, b, c

Remarks: As Glenister and Klapper note (1966, pp.805-806), *Icriodus symmetricus* and *I. nodosus* cannot at present be discriminated with precision; the margin of the basal cavity is broken in the holotype of *I. nodosus* (Huddle, 1934, Pl. 8, figs. 24, 25). *I. nodosus* s.l. is characterized by a sinus in the margin on the inner side of the posterior expansion of the basal cavity, forming a prominent, anteriorly directed spur. Typical specimens of *I. symmetricus* lack such a spur and sinus; however many specimens of very late Middle Devonian age are transitional between *I. symmetricus* and *I. nodosus* s.l. *I. corniger* Wittekindt also has a spur and sinus, and differs from *I. nodosus* s.l. only in that the basal cavity is produced to a sharp point slightly to the outer side of the posterior end. The specimen illustrated as *I. corniger* Wittekindt by van A. Boogaert (Pl. 1, fig. 6a,b) is transitional to *I corniger.* The specimens from the Gneudna Formation are variable; the large figured specimen (Pl.1, fig. 4a,b,c) has a well developed lateral spur which bears a low ridge of fused nodes on its upper surface. In other specimens (not illustrated) the spur is only weakly developed, and these might be referred to *I. symmetricus.* The lateral denticles in all specimens are lachryform; they tend to alternate with the denticles of the middle row, which are laterally compressed. In a few specimens the denticles of the middle row are fused (Pl. 1, fig.5).

Age: I. nodosus s.l. ranges through the Middle Devonian into the lowermost Upper Devonian.

Locality: 17 specimens were recovered from 5 samples from 1052 to 1502 feet (G 10, G 12, G 12c, G 13 G 14+) above the Precambrian contact at the type locality of the Gneudna Formation.

Repository: Figured specimens (UWA 62133, 34. 35).

Genus OZARKODINA Branson & Mehl, 1933

Ozarkodina immersa (Hinde), 1879

Plate 1, figures 10, 11

Remarks: Müller and Clark (1967, p.915) put *O. elegans* Stauffer in synonymy with *O. immersa* by direct comparison with Hinde's type specimen. Note that the specimen figured as Plate 1, figure 11 has two "main" denticles.

Age: Givetian-Frasnian.

Locality: 4 specimens were recovered from 2 samples (G 10, G 13) at the type locality.

Repository: Figured specimens (UWA 62139, 40).

Genus PELEKYSGNATHUS Thomas, 1949

Pelekysgnathus ? sp.

Remarks: A single incomplete specimen was recovered from a nautiloid from Gud 9, approximately 1,000 feet above the base of the Precambrian contact at the type locality. The specimen consists of a single row of denticles with a large posterior denticle, posteriorly inclined. The anterior part is missing. Seen from above and in side view, this specimen would be referred without hesitation to *Pelekysgnathus*, but the basal cavity is unusual: it flares under the terminal denticle, as with *Icriodus* and *Pelekysgnathus,* but instead of tapering towards the anterior end, the flared margins meet abruptly a little anterior to the position of the terminal denticle.

Genus POLYGNATHUS Hinde, 1879

Polygnathus pennatus Hinde, 1879

Plate 1, figures 1a, b, c; 2a, b, c; 3a, b, c

Remarks: Specimens such as those illustrated are familiar to all conodont workers who have examined Givetian-Frasnian faunas. The problem is what to call them. The specimen figured in Plate 1, figure 1a,b,c is typical Gneudna specimen: the high free blade is slightly shorter than the platform, and the basal cavity is about half-way between the mid-point and the anterior margin of the platform. The platform is weakly ribbed. The other two figured specimens are extreme variants. The specimen of Plate 1, figure 3a,b,c is strongly sigmoidal in side view, has a high free blade with fused denticles and a narrow platform with strongly upturned margins and little surface ornament. Specimens such as this are often referred to *P. foliatus* Bryant (e.g., Müller and Clark, 1967, Pl. 115, fig. 4). The specimen of Pl. 1, fig. 2a,b,c resembles *P. eiflia* Bischoff and Ziegler in outline, especially in the flared outer platform margin and anterior constriction, although the platform lacks the nodes and adcarinal ridges of that species. Wittekindt (1966, p.633 redefined *P. ciflia* such that the adcarinal ridges, although characteristic, are not to be considered diagnostic *of P. eiflia.* Thus my specimen might be referred to *P. eiflia,* if the smoothness of the platform be admitted as intra-specific variation.

However, the Gneudna specimens cannot be sorted into three groups and I prefer to regard them as representing a single, rather variable species. *P. pennatus* is the senior species concept, and they are therefore provisionally included in it.

Age: the loosely interpreted *P. foliatus-P. pennatus* group range through the upper Givetian into the Frasnian.

Plate 1 (facing page) Specimens from the type locality of the Gneudna Formation, Carnarvon Basin, Western Australia. All figures are un-retouched photographs. The platform species are coated with ammonium chloride, but the bars and blades (figs. 7-11) are uncoated. Figures 1, 2, 3 and 7 are x40. Figures 4, 5, 6, 8, 9, 10 and 11 are x60, and the bar scale, which represents 1 mm, applies only to these. Figures 1-3.—*Polygnathus pennatus* Hinde. (UWA 62130, 62131, 62132). Figure 1 is a typical specimen; figure 2 has a broader and unornamented platform; figure 3 is a *"P. foliata"* type. (All specimens from G13). Figures 4-6.—*Icriodus nodosus* (Huddle). (UWA 62133, 62134, 62135). Figure 4 has a well developed lateral spur with a prominent node or ridge on the upper surface. In Figure 5 the mid-row of denticles is clearly expressed only in the posterior half, where it is fused into a longitudinal ridge. (G 13, G 10, G 13). Figure 7.—*Angulodus* sp. (UWA 62136; G 13). Figure 8.—*Synprioniodina* sp. cf. *S. prona* (Huddle)? (UWA 62137; G 13). The anticusp is broken off this specimen). Figure 9.—*Synprioniodina* sp. cf. *S. prona* (Huddle).—(UWA 62138; G 13). Figures 10 and 11 —*Ozarkodina immersa* (Hinde). UWA 62139, 62140; G 13).


1
2a
2b
3
4
5
6
7
8
9
10

Locality: 24 specimens were recovered from 4 samples from 1052 to 1480 feet (G 10, G 12c, G 13, G 14) above the Precambrian contact at the type locality of the Gneudna Formation.

Repository: Figured specimens (UWA 62130, 31, 32).

Genus SYNPRIONIODINA Bassler, 1925

Synprioniodina sp. cf. *S. prona* (Huddle), 1934

Plate 1, figure 8 ?, figure 9

Remarks: Huddle (1968) distinguishes *Neoprioniodus* and *Synprioniodina* on the denticulation of the anticusp. '*Neoprioniodus* is distinguished by its non-denticulate anticusp' (p.45) but 'Anticusp not denticulated in most species, but some species have a few denticles' (p.25). The specimen figured here is a borderline case, as the anticusp bears three small, fused denticles. In the specimen figured as *S.* sp. cf. *S. prona* ? (Pl. 1, fig. 8) the anticusp is broken and incomplete. It differs visibly from *S.* sp. cf. *S. prona* only in that the large denticles are wider spaced, with 'germ denticles' between them. The angle between the bar and anticusp cannot be determined.

Localiy: 4 specimens from 2 samples (G 10, G 13).

Repository: Figured specimens (UWA 62137, 38).

Class: OSTEICHTHYES

Sub Class: CHOANICHTHYES

Order: Dipnoi

Family: Dipteridae

Dipterus sp. cf. *D. digitatus* Eastman, 1908

Plate 2, figure 9

1908 *Dipterus digitatus* sp. nov.—Eastman, p. 221-222, Pl. 2, fig. 6; Pl. 7, figs. 16-25.

Orientation: A plaster cast of the head of the Queensland lungfish, *Epiceratodus forsteri* (Pl. 2, fig. 10) shows the orientattion of the dental batteries. The upper plates are the palatal plates, and the lower ones, the mandibular plates. The mandibular plates of most Devonian dipterines are convex, and the palatal plates are flat or slightly concave. The plate illustrated as figure 9 is a presumed right palatal plate: that of figure 8 is a left mandibular plate.

Description: Two specimens have been found, both right palatal plates. The larger of the two (Pl. 2, fig. 9) is 3.5 cms long and 2 cms wide; although extremely well preserved, the margins are broken. The original outline was probably subtriangular. Six costae are preserved; four of these become indistinct at about mid-length. The other two costae fuse at mid-length, and continue as a low, smooth, arcuate ridge to the posterior edge. The costae are tuberculate or noded; the nodes are fused except towards the anterior margin, where they are distinct and well-rounded. The nodes of the most strongly developed costa (second from the inner side) are laterally compressed. The spacing of the costae increases from the outer to the inner margin.

The smaller specimen (2 cms long, 0.9 cms wide) is equally well preserved, but slightly less complete. It differs from the figured specimen only in that the costae just fail to reach the mid-point of the plate, and that there is a well developed sinus between the fused, inner costae and the group of outer costae. Both these characters are shown in the topotypic specimen (Pl. 2, fig. 8) from the State Quarry Limestone of Iowa, but these features were judged to be minor intraspecific variation by Eastman, judging from his illustrations of Plate 7, figures 16-25.

Remarks: Eastman illustrates two distinct lineages from the Devonian of Iowa. One begins with *D. uddeni* from the Middle Devonian, Cedar Valley Limestone. Two Upper Devonian species from the State Quarry Limestone, *D. mordax* and *D. pectinatus* appear to be derived from it. In all these species the many costae run right to the posterior edge, and there is no inner ridge. The nodes of the costae tend to be en echelon, in that their long axes are at an acute angle to the axis of the costae. The dipterines from the Chemung of Eastern North America are of this type.

The second lineage begins with *D. calvini*, also from the Cedar Valley Limestone (from "the *Euomphalus* bed, about 8 feet below the summit of the Middle Devonian in Muscatine County" Eastman 1908, p.220). This species was founded on a single specimen; it has two early Frasnian derivatives, *D. costatus* and *D. digitatus*. All three species have an anterior ridge, which is more strongly developed in the Frasnian spp., and costae which die out at about mid-length. *D. costatus* is distinctive in that the anterior ridge is separated from the other costae by a marked sinus. Eastman does not give a differential diagnosis for *D. calvini* and *D. digitatus,* which look very similar in his illustrations, except that the mandibular plates and *D. digitatus,* which look very similar in his specimens from the Gneudna Formation are presumed to be palatal plates. They should clearly be referred to the *D. calvini-D. digitatus* lineage and should probably be included in the latter species.

Age: The known range of *D. calvini-D. digitatus* is from the late Givetian to early Frasnian.

Locality: The figured specimen was collected from a thick-bedded, blocky limestone 1345 feet above the Precambrian contact at the type locality (sample no. G 13+, a few yards above G 13; the small specimen, from G 7+).

Repository: UWA 62148.

Plate 2 (facing page).—Specimens from the type locality of the Gneudna Formation, Carnarvon Basin, Western Australia. All figures are un-retouched photographs. The specimens are coated with ammonium chloride. Figures 1-7 are approximately x45, as is the scale. Figure 1.—Fish tooth; type a (UWA 62141; G 13e). Figure 2.—Fish tooth; type b (UWA 62142; G 10). Figure 3.—Fish tooth; type c (UWA 62143; G 9c). Figure 4.— Fish scale (UWA 62144; G 13). Figure 5.—Conical fish tooth; type d (UWA 62145; G 13). Figure 6.—Fish tooth; type e (UWA 62146; G 8p). Figure 7.—Acanthodian fin scale? (UWA 62147; G 13). Figure 8.—*Dipterus digitatus* Eastman. Left mandibular plate. *Synthetodus* zonule, North Liberty Phase, State Quarry, Johnson Co., Iowa. Basal U. Dev. (C. H. Belanski Collection, W. Aust. Mus. 64.10.5; x 1.4). Figure 9.—*Dipterus* sp. cf. *D. digitatus* Eastman. Right palatal plate (UWA 62148; G 7 +; x 1.4). Figure 10.—*Neoceratodus forsteri.* Plaster cast of Queensland lungfish head showing palatal teeth. (W. Aust. Mus. PIQ05; about 2/3rds natural size).

The "Euomphalus bed" of Eastman is now referred to the *Straparollus* zone: it constitutes the uppermost of the three biotic units of the uppermost member (Coralville Member) of the Cedar Valley Limestone. Klapper (in Glenister and Rexroad, 1968, pp.6-12) notes the occurrence of *Spathognathodus insitus* in the top foot of the section at Muscatine County, suggesting that the uppermost bed of the Coralville Member at Sweetland Creek may be low Upper Devonian. It is at least clear that *D. calvini* and *D. digitatus* differ only very slightly in morphology and in age, both occurring near the Middle/Upper Devonian boundary.

Vertebrate fragments

In some samples fish scales and teeth are very abundant. These are of several distinct kinds. Some are hollow (Pl. 2, fig. 2a,b; fig. 6). Both of these specimens are waisted, in that there is a constriction in the side walls just above the base. The specimen illustrated as Plate 2, figure 2a,b resembles a viking's helmet and represents a distinct form, but there are variants which link it with figure 6, the difference being whether the ridges meet concentrically or excentrically. Figures 1 and 3 are not hollow, and have a flat base; one is a three sided, and the other a four sided pyramid. Figure 5 is a simple, hollow, thick walled conical tooth: these are extremely abundant in most samples. Figures 4 and 7 also illustrate abundant material. Figure 4 is a more or less rhomboidal or sinusoidal scale; Philip (1965, pl. 8, fig. 42) illustrates an ornamented plate like that of figure 7, and considers that it probably represents an acanthodian fin spine. Dr. J. W. Warren, Monash University, has looked at this material: in his view it can possibly be referred to the *Holoptychiidae*, or more probably *Struniiformes* (Jessen, 1965). He considers specimens like those from the Gneudna Formation to be limited to Devonian deposits, and to be far more common in the Middle Devonian than in the Lower or Upper Devonian.

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